PISA

PISA 2022 Assessment and Analytical Framework

OECD

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Foreword

The OECD Programme for International Student Assessment (PISA) assesses the extent to which 15-year-old students near the end of their compulsory education have acquired the knowledge and skills that are essential for full participation in modern societies. The assessment does not just ascertain whether students can reproduce knowledge; it also examines how well students can extrapolate from what they have learned and can apply that knowledge in unfamiliar settings, both in and outside of school. This approach reflects the fact that modern economies reward individuals not for what they know, but for what they can do with what they know.

The assessment focuses on the core domains of reading, mathematics and science. Students' proficiency in an innovative domain is also assessed; in PISA 2022, this domain was creative thinking.

PISA is a triennial assessment that was launched in 1997 and implemented for the first time in 2000. For the eighth cycle of PISA, the PISA Governing Board (PGB) decided to postpone the assessment from 2021 to 2022 due to the COVID-19 pandemic. Thus, there was an exceptional four-year cycle between PISA 2018 and PISA 2022.

This publication presents the theory underlying the PISA 2022 assessment. It includes frameworks for assessing mathematics, the fourth assessment of students' financial literacy, and the framework for assessing the innovative domain, creative thinking. These chapters outline the content knowledge that students need to acquire in each domain, the processes that students need to be able to perform, and the contexts in which this knowledge and these skills are applied. The publication also discusses how each domain is assessed. Subsequently, the publication presents the frameworks for the various questionnaires distributed to students, school principals, parents, and teachers, including a new Global Crisis Module for students and school principals. It concludes with the framework for the Information and Communications Technology (ICT) familiarity questionnaire distributed to students.

In PISA 2022, mathematics was the major domain of assessment, as it was in 2003 and 2012. While appreciating and preserving the basic ideas of mathematical literacy developed in 2003 and 2012, the assessment in 2022 acknowledges a number of shifts in the world of the student which in turn signals a shift on how to assess mathematics in comparison to the approach used in previous frameworks. The new framework reflects a rapidly changing world driven by new technologies and trends in which citizens are creative and engaged, making judgements for themselves and the society in which they live.

PISA is the product of a collaborative effort between OECD and the governments of both OECD countries and its partner countries/economies. The assessments are developed co-operatively, agreed by participating countries/economies, and implemented by national organisations. The co-operation of students, teachers and principals in participating schools has been crucial to the success of PISA during all stages of development and implementation.

The mathematics framework was developed under the guidance of the 2022 mathematics expert group (MEG) chaired by Joan Ferrini-Mundy (University of Maine, United States)and Zbigniew Marciniak (University of Warsaw, Poland). Other experts who contributed to the mathematics framework are William Schmidt (Michigan State University, United States), Shuchi Grover (Stanford University, United States), Takuya Baba (Hiroshima University, Japan), Jenni Ingram (University of Oxford, United Kingdom), Julián Mariño (University of the Andes, Colombia), and Stefania Bocconi (National Research Council of Italy (CNR) Institute for Educational Technology, Italy). The MEG was further supported by an extended MEG (eMEG) group, made up of ten experts acting as peer reviewers of the framework version created by the MEG. The eMEG included Michael Besser (Leuphana University of Lüneburg, Germany), Jean-Luc Dorier (University of Geneva, Switzerland), Iddo Gal (University of Haifa, Israel), Markku Hannula (University of Helsinki, Finland), Hannes Jukk (University of Tartu, Estonia), Christine Stephenson (University of Tennessee, United States), Tin Lam Toh (Nanyang Technological University, Singapore), Ödön Vancsó (Eötvös Loránd University, Hungary), David Weintrop (College of Information Studies, University of Maryland, United States), and Richard Wolfe (Ontario Institute for Studies in Education, University of Toronto, Canada). The work of the PISA 2022 MEG builds on previous versions of the PISA Mathematics framework and incorporates the recommendations of the Mathematics Strategic Advisory Group convened by OECD in 2017.

The financial literacy 2022 framework was revised by Chiara Monticone and Flore-Anne Messy of the OECD Secretariat with the Financial Literacy Expert Group (FLEG). The FLEG included Carmela Aprea (University of Mannheim, Germany), José Alexandre Cavalcanti Vasco (Securities and Exchange Commission, Brazil), Paul Gerrans (University of Western Australia, Australia), David Kneebone (Investor Education Centre, Hong Kong (China)), Sue Lewis (Financial Services Consumer Panel, United Kingdom), Annamaria Lusardi (George Washington University School of Business and Global Financial Literacy Excellence Center, United States), Olaf Simonse (Ministry of Finance, Netherlands), Anna Zelentsova (Ministry of Finance of the Russian Federation, Russia). The 2022 revision built on the initial PISA 2012 financial literacy framework developed by the FLEG, that at the time was composed of Annamaria Lusardi (The George Washington University School of Business, United States), Jean-Pierre Boisivon (Université de Paris II Panthéon-Assas, France), Diana Crossan (Commission for Financial Literacy and Retirement Income, New Zealand), Peter Cuzner (Australian Securities and Investments Commission, Australia), Jeanne Hogarth (Federal Reserve System, United States), Dušan Hradil, (Ministry of Finance, Czech Republic), Stan Jones (Consultant, Canada), and Sue Lewis, (Consultant, United Kingdom).

The creative thinking framework was developed by Natalie Foster and Mario Piacentini of the OECD Secretariat, under the guidance of the creative thinking expert group (CTEG). The CTEG included Ido Roll (Technion – Israel Institute of Technology, Israel), Baptiste Barbot (Université Catholique de Louvain, Belgium), Lene Tanggaard (Aalborg University, Denmark), Nathan Zoanetti (Australian Council for Educational Research, Australia), James Kaufman (University of Connecticut, United States), Marlene Scardamalia (University of Toronto, Canada) and Valerie Shute (Florida State University, United States). Natalie Laechelt (OECD Secretariat) also contributed to the research for the creative thinking framework. Bill Lucas (University of Winchester, United Kingdom), Jack Buckley (Roblox, United States), and Bo Stjerne Thomsen (LEGO Foundation, Denmark) provided precious advice and reviewed the drafts of the framework.

The framework for the PISA 2022 questionnaires was developed by Jonas Bertling, Jan Alegre, and Katie Faherty (Educational Testing Service, United States) with the guidance of and input from the questionnaire expert group. The questionnaire expert group was chaired by Nina Jude (Leibniz Institute for Research and Information in Education (DIPF) until 2020, then Heidelberg University, Germany). This group included Hunter Gehlbach (University of California, Santa Barbara until 2019, then Johns Hopkins University, United States), Kit-Tai Hau (The Chinese University of Hong Kong, Hong Kong (China)), Therese Hopfenbeck (University of Oxford, United Kingdom until 2022, then University of Melbourne, Australia), David Kaplan (University of Wisconsin-Madison, United States), Jihyun Lee (University of New South Wales, Australia), Richard Primi (Universidade São Francisco, Brazil), and Wilima Wadhwa (ASER Centre, India).

The framework for the PISA 2022 ICT familiarity questionnaire was developed by Adrien Lorenceau, Camille Marec and Tarek Mostafa (OECD) with the guidance of and input from the ICT expert group. The ICT expert group was chaired by Michael Trucano (World Bank, United States). This expert group included

Jepe Bundsgaard (University of Aarhus, Denmark), Cindy Ong (Ministry of Education, Singapore), Patricia Wastiau (European Schoolnet, Belgium) and Pat Yongpradit (Code.org, United States). The work on developing the PISA 2022 ICT framework was co-funded by the European Commission.

The Research Triangle Institute (RTI International) and its subcontractor, Pearson Education Limited, facilitated the development of the framework for mathematics. Educational Testing Service (ETS) had responsibility for the revision and development of the framework for questionnaires (non-cognitive outcomes and contextual information) using the existing frameworks as a base. ETS was also responsible for managing and overseeing this survey, developing the instruments, scaling, analysis, and developing the PISA computer platform and the communication portal. Other partners or subcontractors involved with ETS include the University of Luxembourg, the consultant Béatrice Halleux, the Centre for the Analysis of Systems and Practices in Education (aSPe) at the University of Liege, and Westat. ACT, Inc. had the responsibility for the instrument development of the PISA 2021 innovative domain: creative thinking. The responsibility for sampling was assumed by Westat as an independent contractor. cApStAn was responsible for linguistic quality assurance and management, and linguistic quality control, ensuring the linguistic equivalence of all language versions. The Australian Council for Educational Research (ACER) oversaw the optional programme for preparation and implementation support to countries.

The publication was prepared by the OECD Secretariat. Juliana González Rodríguez co-ordinated the production of the framework with Tue Halgreen and Catalina Covacevich, and contributions from Miyako Ikeda and Tiago Fragoso. Cassandra Morley and Charlotte Baer provided communications assistance, and Ricardo Sanchez Torres provided editorial and administrative support.

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1 What is PISA?

This chapter introduces the PISA 2022 Assessment and Analytical Framework. It describes what makes PISA unique, the key features of the PISA 2022 test, an overview of what is assessed in each domain, the evolution of reporting student performance and the context questionnaires. Finally, it presents how PISA is the result of a collaborative effort.

The OECD Programme for International Student Assessment (PISA), now in its eighth cycle, seeks to determine what is important for citizens to know and be able to do. PISA assesses the extent to which 15-year-old students near the end of their compulsory education have acquired the knowledge and skills that are essential for full participation in modern societies.

The assessment focuses on the core school subjects of reading, mathematics, and science. Students' proficiency in an innovative domain is also assessed; in 2022, this domain was creative thinking. The assessment does not just ascertain whether students can reproduce knowledge; it also examines how well students can extrapolate from what they have learned and can apply that knowledge in unfamiliar settings, both in and outside of school. This approach reflects the fact that modern economies reward individuals not for what they know, but for what they can do with what they know.

PISA is an ongoing programme that monitors trends in the knowledge and skills that students around the world, and in demographic subgroups within each country, have acquired. In each round of PISA, one of the core domains, denominated major domain, is tested in detail, taking up roughly one-half of the total testing time. The major domain in 2022 was mathematics as it was in 2003 and 2012. Reading was the major domain in 2000, 2009 and 2018, and science was the major domain in 2006 and 2015.

With this alternating schedule of major domains, a thorough analysis of achievement in each of the three core areas is presented every nine years; an analysis of trends is offered every three years. However, due to the decision to postpone the assessment from 2021 to 2022 to reflect post-COVID difficulties, the analysis of achievement and trends from the results of this cycle will be offered one year later than in previous cycles.

Through questionnaires distributed to students and school principals, and optional questionnaires distributed to parents and teachers, PISA also gathers information about students' home background, their approaches to learning and their learning environments. Combined with the information gathered through the various questionnaires, the PISA assessment provides three main types of outcomes:

- basic indicators that provide a profile of the knowledge and skills of students;
- indicators derived from the questionnaires that show how such skills relate to various demographic, social, economic and educational variables;
- indicators on trends that show changes in outcomes and their distributions, and in relationships between student-, school- and system-level background variables and outcomes.

Policymakers around the world use PISA findings to gauge the knowledge and skills of the students in their own country/economy compared with those in other participating countries/economies, establish benchmarks for improvements in the education provided and/or in learning outcomes, and understand the relative strengths and weaknesses of their own education systems.

This publication presents the theory underlying the PISA 2022 assessment – the eighth since the programme's inception. It includes the frameworks for assessing the major domain, mathematics (Chapter 2); students' financial literacy (Chapter 3); and the innovative domain, creative thinking (Chapter 4). These chapters outline the knowledge content that students need to acquire in each domain, the processes that students need to be able to perform, and the contexts in which this knowledge and these skills are applied. They also discuss how each domain is assessed. The publication concludes with the frameworks for the various questionnaires distributed to students, school principals, parents and teachers (Chapter 5), and the framework for the information and communications technology (ICT) familiarity questionnaire distributed to students (Chapter 6). The frameworks for the reading and science assessments are not included in this publication as they received their last major updates when they were the major domain of assessment (2018 for reading, 2015 for science), links to access their full versions are included as Annexes (Annex A and Annex B, respectively).

Box 1.1. Key features of PISA 2022

The content

PISA not only assesses whether students can reproduce knowledge, but also whether they can extrapolate from what they have learned and apply their knowledge in new situations. It emphasises the mastery of processes, the understanding of concepts, and the ability to function in various types of situations.

The PISA 2022 survey focused on mathematics, with reading and science as minor domains of assessment. For the first time, creative thinking was assessed as an innovative domain. PISA 2022 also included an assessment of young people's financial literacy, which was optional for countries and economies.

The students

Some 690 000 students completed the assessment in 2022, representing about 29 million 15-year-olds in the schools of the 81 participating countries/economies.

The assessment

Computer-based tests were used, with assessments lasting a total of two hours for each student.

Test items were a mixture of multiple-choice questions and questions requiring students to construct their own responses. The items were organised in groups based on a passage setting out a real-life situation. Over 15 hours of test items were used, with different students taking different combinations of test items.

Students also answered a background questionnaire that took 35 minutes to complete. The questionnaire sought information about the students themselves, their homes, and their school and learning experiences. School principals completed a questionnaire that covered the school system and the learning environment. In addition, a new Global Crisis Module was included to collect information on COVID-19-related disruptions to students' learning and well-being in participating education systems.

To obtain additional information, some countries/economies decided to distribute a questionnaire to teachers to learn about their training and professional development, their teaching practices and their job satisfaction. In some countries/economies, optional questionnaires were distributed to parents, who were asked to provide information on their perceptions of and involvement in their child's school, their support for learning in the home, and their own engagement with mathematics.

Countries/economies could also choose an optional questionnaire for students about their familiarity with and use of information and communications technologies. A financial literacy questionnaire was also distributed to the students in the countries/economies that conducted the optional financial literacy assessment.

What makes PISA unique

PISA is the most comprehensive and rigorous international programme to assess student performance and to collect data on the student, family and institutional factors that can help explain differences in performance. Decisions about the scope and nature of the assessments and the background information to be collected are made by leading experts in participating countries, and are steered jointly by governments on the basis of shared, policy-driven interests. Substantial efforts and resources are devoted to achieving cultural and linguistic breadth and balance in the assessment materials. Stringent quality-assurance mechanisms are applied in translation, sampling, and data collection. As a consequence, results from PISA have a high degree of validity and reliability.

PISA's unique features include its:

- **policy orientation**, which links data on student learning outcomes with data on students' backgrounds and attitudes towards learning, and on key factors that shape their learning in and outside of school; this exposes differences in performance and identifies the characteristics of students, schools and education systems that perform well;
- **innovative concept of "literacy"**, which refers to students' capacity to apply knowledge and skills, and to analyse, reason and communicate effectively as they identify, interpret and solve problems in a variety of situations;
- **relevance to lifelong learning**, as PISA asks students to report on their motivation to learn, their beliefs about themselves and their learning strategies;
- **regularity**, which enables countries to monitor their progress in meeting key learning objectives;
- **breadth of coverage**, which, in PISA 2022, encompassed 37 OECD countries and 44 partner countries and economies.

The PISA 2022 test

The PISA 2022 assessment was conducted principally via computer, as was the case, in 2015 and 2018. Paper-based assessment (PBA) instruments were provided for countries that cannot test their students by computer; but the paper-based assessment was limited to reading, mathematics and science trend items only (i.e. those items that had already been used in prior paper-based assessments). New items were developed only for the computer-based assessment (CBA). Regardless of the delivery mode, the assessment consisted of a cognitive testing session of 120 minutes, followed by a student questionnaire session of approximately 35 minutes.

The PISA 2022 design continued to leverage the innovations made possible by change to CBA as a main mode of assessment in PISA 2015, such as the multistage adaptive testing (MSAT) design implemented in 2018 for reading. The MSAT design for PISA 2022 mathematics builds on and improves on the reading design by 1) presenting items across all stages of the adaptive design, fully balancing item positions and further mitigating possible position effects, 2) using a linear-adaptive hybrid design that assigns students to a fully adaptive MSAT or a linear form to further optimise the data collection for scaling, and 3) using mathematical optimisation methods to optimise the assembly of the cognitive test, both on its linear and its adaptive formats. The 2022 MSAT reading design is the same as in 2018, albeit in a reduced form to account for a smaller item pool since it is a minor domain in this PISA cycle. More detail on the MSAT design employed in PISA 2022 can be found on its Technical Report (OECD, forthcoming).

There were six different kinds of test forms representing various combinations of two of the four domains (i.e., the three core domains, plus the innovative domain). For the CBA design with creative thinking, ninety-four percent of students received test forms involving 60 minutes of mathematics as the major domain, and 60 minutes of one of the three minor or innovative domains (reading, science, or creative thinking). In addition, six percent of students received test forms composed of two minor domains, this aims to fully allow for the estimation of covariance between any two given pair of domains.

Each test form was completed by a sufficient number of students to allow for estimations of proficiency and psychometric analysis of all items by students in each country/economy and in relevant subgroups within a country/economy, such as boys and girls, or students from different social and economic backgrounds.

The assessment of Financial Literacy was offered again in PISA 2022 as an optional CBA component. It was based on a revised Financial Literacy framework founded on the PISA 2022 updated framework. The cognitive instruments included trend items plus a set of new interactive items that were developed specifically for PISA 2022.

An overview of what is assessed in each domain

Box 1.2 presents definitions of the three domains assessed in PISA 2022. The definitions all emphasise the functional knowledge and skills that allow one to participate fully in society. Such participation requires more than just the ability to carry out tasks imposed externally by, for example, an employer; it also involves the capacity to participate in decision making. The more complex tasks in PISA require students to reflect on and evaluate material, not just answer questions that have one correct answer.

Box 1.2. Definitions of the domains

Mathematics: In mathematics, PISA measures an individual's capacity to reason mathematically and to formulate, employ, and interpret mathematics to solve problems in a variety of real-world contexts. The framework includes concepts, procedures, facts, and tools to describe, explain and predict phenomena. It assists individuals to know the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective 21st century citizens.

Reading: The reading assessment in PISA measures an individual's capacity to understand, use, evaluate, reflect on, and engage with texts in order to achieve one's goals, develop one's knowledge and potential, and participate in society.

Science: The science assessment in PISA covers the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically.

Mathematical literacy (Chapter 2) is defined as students' ability to reason mathematically and to formulate, employ, and interpret mathematics to solve problems in a variety of real-world contexts.

PISA assesses students' performance in mathematics through questions related to:

- **Mathematical Reasoning and Problem-Solving Processes:** Includes the mathematical processes that describe what individuals do to connect the context of the problem with mathematics and thus solve the problem.

  Mathematical reasoning (both deductive and inductive) involves evaluating situations, selecting strategies, drawing logical conclusions, developing and describing solutions, and recognising how those solutions can be applied. It is enabled by some key understandings that undergird school mathematics, is the core of mathematical literacy. Included among these key understandings are: understanding quantity, number systems and their algebraic properties; appreciating the power of abstraction and symbolic representation; seeing mathematical structures and their regularities; recognising functional relationships between quantities; using mathematical modelling as a lens onto the real world (e.g. those arising in the physical, biological, social, economic, and behavioural sciences); and understanding variation as the heart of statistics. Regarding problem solving, PISA defines three categories of processes: formulating situations mathematically; employing mathematical concepts, facts, procedures and reasoning; and interpreting, applying and evaluating mathematical outcomes.

- **Content**: There are four categories (change and relationships; quantity; space and shape; and uncertainty and data) that are closely aligned with the content that is typically found in national school mathematics curricula content strands, such as numbers, algebra, functions, geometry, and data handling.
- **Context**: The aspect of an individual's world in which the problems are placed. The framework identifies four contexts: personal, occupational, societal and scientific.

Reading literacy is defined as students' ability to understand, use, evaluate, reflect on and engage with text to achieve their purposes.

PISA assesses students' performance in reading through questions that involve a variety of:

- **Processes (aspects)**: Students are not assessed on the most basic reading skills, as it is assumed that most 15-year-old students will have acquired these. Rather, students are expected to demonstrate their proficiency in locating information, including both accessing and retrieving information within a piece of text, and searching for and selecting relevant text; understanding text, including both acquiring a representation of the literal meaning of text and constructing an integrated representation of text; and evaluating and reflecting on text, including both assessing its quality and credibility, and reflecting on content and form.
- **Text formats**: PISA uses both single-source and multiple-source texts; static and dynamic texts; continuous texts (organised in sentences and paragraphs); non-continuous texts (e.g. lists, forms, graphs or diagrams); and mixed texts.
- **Situations**: These are defined by the use for which the text was constructed. For example, a novel, personal letter or biography is written for people's personal use; official documents or announcements are for public use; a manual or report is for occupational use; and a textbook or worksheet is for educational use. Since some students may perform better in one type of reading situation than another, a range of reading situations is included in the test.

Scientific literacy is defined as the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically.

PISA assesses students' performance in science through questions related to:

- **Context**: This includes personal, local/national and global issues, both current and historical, that demand some understanding of science and technology.
- **Knowledge**: This is the understanding of the major facts, concepts and explanatory theories that form the basis of scientific knowledge. Such knowledge includes knowledge of both the natural world and technological artefacts (content knowledge), knowledge of how such ideas are produced (procedural knowledge), and an understanding of the underlying rationale for these procedures and the justification for their use (epistemic knowledge).
- **Competencies:** These are the ability to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically.

The evolution of reporting student performance in PISA

Results from PISA are reported using scales. Initially, the average score across OECD countries for all three subjects was 500 with a standard deviation of 100, which meant that two-thirds of students across OECD countries scored between 400 and 600 points. These scores represent degrees of proficiency in a particular domain. Scores in subsequent cycles of PISA are calibrated so as to be directly comparable to those in previous cycles; hence the average score across OECD countries in subsequent cycles has fluctuated slightly around the original 500.

Reading literacy was the major domain in 2000, and the reading scale was divided into five proficiency levels of knowledge and skills. The main advantage of this approach is that it is useful for describing what substantial numbers of students can do with tasks at different levels of difficulty. PISA 2003 built upon this approach by specifying six proficiency levels for the mathematics scale. There were four “content” subscales in mathematics: space and shape, change and relationships, quantity, and uncertainty.

In PISA 2012 mathematics was re-assessed as a major domain, and, in addition to the content subscales (with the uncertainty scale being renamed as uncertainty and data for improved clarity), three new subscales were developed to point to the three processes in which students as active problem solvers will engage. These three process subscales are formulating situations mathematically; employing mathematical concepts, facts, procedures and reasoning; and interpreting, apply and evaluating mathematical outcomes, abbreviated as formulating, employing, and interpreting.

Mathematics was once again the major domain of assessment in PISA 2022. The six proficiency levels reported for the overall PISA mathematics in previous cycles were expanded as follows: Level 1 will be renamed Level 1a, and the table describing the proficiencies will be extended to include Levels 1b and 1c. These additional levels have been added to provide greater granularity of reporting in students performing at the lower end of the proficiency scale.

The context questionnaires

To gather contextual information, PISA asks students and the principals of their schools to respond to questionnaires. These take about 35 and 45 minutes, respectively, to complete. The responses to the questionnaires are analysed with the assessment results to provide at once a broader and more nuanced picture of student, school and system performance. Chapter 5 presents the questionnaire framework in detail. The questionnaires from all assessments since PISA’s inception are available on the PISA website: www.oecd.org/pisa/.

The questionnaires seek information about:

- students and their family background, including their economic, social and cultural capital;
- aspects of students’ lives, such as their attitudes towards learning, their habits and life in and outside of school, and their family environment;
- aspects of schools, such as the quality of the schools’ human and material resources, public and private management and funding, decision-making processes, staffing practices, and the school’s curricular emphasis and extracurricular activities offered;
- context of instruction, including institutional structures and types, class size, classroom and school climate, and reading activities in class;
- aspects of learning, including students’ interest, motivation and engagement.

Additionally, the PISA 2022 context questionnaires collected information on COVID-19-related disruptions to students’ learning and well-being in participating education systems. This information can provide context for understanding PISA 2022 results, as well as serve to advance policy discussions about fostering the resiliency of students, schools, and education systems in responding to educational disruptions arising from ongoing and future global crises.

In PISA 2022, three additional questionnaires were offered as options:

- **computer familiarity questionnaire**, focusing on the availability and use of ICT and on students' ability to carry out computer tasks and their attitudes towards computer use;
- **parent questionnaire**, focusing on parents' perceptions of and involvement in their child's school, their support for learning at home, school choice, their child's career expectations, and their background (immigrant/non-immigrant);
- **teacher questionnaire**, which asks about teachers' initial training and professional development, their beliefs and attitudes, and their teaching practices; separate questionnaires were developed for teachers of the test language and for other teachers in the school.

The contextual information collected through the student, school and optional questionnaires comprises only a part of the information available to PISA. Indicators describing the general structure of education systems (their demographic and economic contexts, such as their costs, enrolments, school and teacher characteristics, and some classroom processes) and their effect on labour market outcomes are routinely developed and applied by the OECD (e.g. in the annual OECD publication, *Education at a Glance*).

A collaborative project

PISA is the result of a collaborative between the OECD Secretariat, international contractors, experts, and teams at participating countries and economies. The assessments are developed co-operatively, agreed by participating countries/economies, and implemented by national centres in each participant. The co-operation of students, teachers and principals in participating schools has been crucial to the success of PISA during all stages of development and implementation.

The PISA Governing Board (PGB), composed of representatives at the senior policy level from all participating countries/economies, determines the policy priorities for PISA. It also oversees adherence to these priorities during the implementation of the programme. The PGB sets priorities for developing indicators, establishing assessment instruments and reporting results. Experts from participating countries/economies also serve on working groups tasked with linking PISA policy objectives with the best available technical expertise in the different assessment domains. By participating in these expert groups, countries/economies ensure that the instruments are internationally valid and take into account differences in cultures and education systems.

Participating countries/economies implement PISA at the national level through National Centres managed by National Project Managers, subject to the agreed administration procedures. National Project Managers play a vital role in ensuring that the implementation is of high quality. They also verify and evaluate survey results, analyses, reports and publications.

The frameworks were developed under the guidance of expert groups (Annex C). The OECD Secretariat has overall managerial responsibility for the programme, monitors its implementation on a day-to-day basis, acts as the secretariat for the PGB, builds consensus among countries, and serves as the interlocutor between the PGB and the international contractors charged with implementation. The OECD Secretariat is also responsible for producing the indicators, and for the analysis and preparation of the international reports and publications, in co-operation with the contractors and in close consultation with participating countries/economies at both the policy (PGB) and implementation (National Project Managers) levels.

2 PISA 2022 Mathematics Framework

Mathematics is the major domain of assessment of the 2022 cycle of the Programme for International Student Assessment (PISA). The mathematics framework presented in this chapter was considerably updated for the PISA 2022 assessment. The chapter outlines the “organisation of the domain”, in four aspects: a) mathematical reasoning and its three processes; b) the way mathematical content knowledge is organised in the PISA 2022 framework; c) the relationship between mathematical literacy and 21st Century skills; and d) contexts in which students face mathematical challenges. Moreover, the chapter outlines structural aspects of the assessment, including a test blueprint and other technical information. Various sample items from the mathematics assessment are included at the end of this chapter.

Introduction

The assessment of mathematics has particular significance for PISA 2022, as it is the major domain assessed. Although it was assessed by PISA in 2000, 2003, 2006, 2009, 2012, 2015 and 2018, the domain was the main area of focus only in 2003 and 2012.

The return of mathematics as the major domain in PISA 2022 provides both the opportunity to continue to make comparisons in student performance over time, and to re-examine what should be assessed in light of changes that have occurred in the world, the field and in instructional policies and practices.

Each country has a vision of mathematical competence and organises their schooling to achieve it as an expected outcome. Mathematical competence historically encompassed performing basic arithmetic skills or operations, including adding, subtracting, multiplying, and dividing whole numbers, decimals, and fractions; computing percentages; and computing the area and volume of simple geometric shapes. In recent times, the digitisation of many aspects of life, the ubiquity of data for making personal decisions involving initially education and career planning, and, later in life, health and investments, as well as major societal challenges to address areas such as climate change, governmental debt, population growth, spread of pandemic diseases and the globalising economy, have reshaped what it means to be mathematically competent and to be well equipped to participate as a thoughtful, engaged, and reflective citizen in the 21st Century.

The critical issues listed above as well as others that are facing societies throughout the world all have a quantitative component to them. Understanding them, as well as addressing them, at least in part, requires being mathematically literate and thinking mathematically. Such mathematical thinking in more and more complex contexts is not driven by the reproduction of the basic computational procedures mentioned earlier, but rather by reasoning[1] (both deductive and inductive). The important role of reasoning needs greater emphasis in our understanding of what it means for students to be mathematically literate. In addition to problem solving, this framework argues that mathematical literacy in the 21st Century includes mathematical reasoning and some aspects of computational thinking.

Countries today face new opportunities and challenges in all areas of life, many of which stem from the rapid deployment of computers and devices like robots, smartphones and networked machines. For example, the vast majority of young adults and students who started university post 2015 have always considered phones to be mobile hand-held devices capable of sharing voice, texts, and images and accessing the internet – capabilities seen as science fiction by many of their parents and certainly by all of their grandparents (Beloit College, 2017[1]). The recognition of the growing contextual discontinuity between the last century and the future has prompted a discussion around the development of 21st Century skills in students (Ananiadou and Claro, 2009[2]; Fadel, Bialik and Trilling, 2015[3]; National Research Council, 2012[4]; Reimers and Chung, 2016[5]).

It is this discontinuity that also drives the need for education reform and the challenge of achieving it. Periodically, educators, policy makers, and other stakeholders revisit public education standards and policies. In the course of these deliberations new or revised responses to two general questions are generated: 1) what do students need to learn?, and 2) which students need to learn what?. The most used argument in defence of mathematics education for all students is its usefulness in various practical situations. However, this argument alone gets weaker with time – a lot of simple activities have been automated. Not so long ago, waiters in restaurants would multiply and add on paper to calculate the price to be paid. Today they just press buttons on hand-held devices. Not so long ago, people used printed timetables to plan travel – it required a good understanding of the time axis and inequalities as well as interpreting complex two-way tables. Today we can just make a direct internet inquiry.

As to the question of "what to teach", many restrictive understandings arise from the way mathematics is conceived. Many people see mathematics as no more than a useful toolbox. A clear trace of this approach can be found in the school curricula of many countries. These are sometimes confined to a list of mathematics topics or procedures, with students asked to practice a selected few, in predictable (often test) situations. This perspective on mathematics is far too narrow for today's world. It overlooks key features of mathematics that are growing in importance. Notwithstanding the above remark, there are an increasing number of countries that emphasise reasoning and the importance of relevant contexts in their curricula. Perhaps these countries cab serve as helpful models to others.

Ultimately the answer to these questions is that every student should learn (and be given the opportunity to learn) to think mathematically, using mathematical reasoning (both deductive and inductive) in conjunction with a small set of fundamental mathematical concepts that support this reasoning and which themselves are not necessarily taught explicitly but are made manifest and reinforced throughout a student's learning experiences. This equips students with a conceptual framework through which to address the quantitative dimensions of life in the 21st Century.

The PISA 2022 framework is designed to make the relevance of mathematics to 15-year-old students clearer and more explicit, while ensuring that the items developed remain set in meaningful and authentic contexts. The mathematical modelling cycle, used in earlier frameworks (e.g. OECD (2004[6]; 2013[7])) to describe the stages individuals go through in solving contextualised problems, remains a key feature of the PISA 2022 framework. It is used to help define the mathematical processes in which students engage as they solve problems – processes that together with mathematical reasoning (both deductive and inductive) will provide the primary reporting dimensions.

For PISA 2022, computer-based assessment of mathematics (CBAM) will be the primary mode of delivery for assessing mathematical literacy. However, paper-based assessment instruments will be provided for countries choosing not to test their students by computer. The framework has been updated to also reflect the change in delivery mode introduced in 2015, including a discussion of the considerations that should inform the development of the CBAM items as this will be the first major update to the mathematics framework since computer-based assessment was introduced in PISA.

The development of the PISA 2022 framework takes into account the expectation of OECD that there will be an increase in the participation in PISA of low- and middle-income countries. In particular the PISA 2022 framework recognises the need to increase the resolution of the PISA assessments at the lower end of the student performance distribution by drawing from the PISA for Development (OECD, 2017[8]) framework when developing the assessment; the need to expand the performance scale at the lower end; the importance of capturing a wider range of social and economic contexts; and the anticipation of incorporating an assessment of out-of-school 14- to 16-year-olds.

The increasing and evolving role of computers and computing tools in both day-to-day life and in mathematical literacy problem solving contexts is reflected in the recognition in the PISA 2022 framework that students should possess and be able to demonstrate computational thinking skills as they apply to mathematics as part of their problem-solving practice. Computational thinking skills include pattern recognition, designing and using abstraction, pattern decomposition, determining which (if any) computing tools could be employed in analysing or solving a problem, and defining algorithms as part of a detailed solution. By foregrounding the importance of computational thinking as it applies to mathematics, the framework anticipates a reflection by participating countries on the role of computational thinking in mathematics curricula and pedagogy.

The PISA 2022 mathematics framework is organised into three major sections. The first section, "Definition of Mathematical Literacy", explains the theoretical underpinnings of the PISA mathematics assessment, including the formal definition of the *mathematical literacy* construct. The second section, 'Organisation of the Domain', describes four aspects: a) mathematical reasoning and the three mathematical *processes* (of the modelling/problem solving cycle); b) the way mathematical *content* knowledge is organised in the PISA 2022 framework, and the content knowledge that is relevant to an assessment of 15-year-old students; c) the relationship between mathematical literacy and the so-called *21st Century skills*; and d) the *contexts* in which students will face mathematical challenges. The third section, "Assessing Mathematical

Literacy", outlines structural issues about the assessment, including a test blueprint and other technical information.

For the sake of ensuring the preservation of trend, the majority of the items in the PISA 2022 will be items that have been used in previous PISA assessments. A large collection of release items based on the previous framework can be found at http://www.oecd.org/pisa/test. **Annex A** provides seven illustrative items that attempt to illustrate the most important new elements of the 2022 framework.

The 2022 framework was written under the guidance of the mathematics expert group (MEG), a body appointed by the PISA contractor for the mathematics framework (RTI International), in consultation with the PISA Governing Board (PGB). The eight MEG members included mathematicians, statisticians, mathematics educators, and experts in assessment, technology, and education research from a range of countries. The MEG were further supported by an extended MEG (eMEG) group, made up of ten experts acting as peer reviewers of the framework version created by the MEG. The eMEG included experts with a range of mathematics expertise from differing countries. Additional reviews were undertaken by experts on behalf of the over 80 countries constituting the PISA Governing Board. RTI International, as contracted by the Organisation for Economic Co-operation and Development (OECD), conducted two further research efforts: a face validity validation survey amongst educators, universities and employers; and a cognitive laboratory with 15-year-olds in different countries to obtain student feedback on the sample items presented in the framework. The work of the MEG builds on previous versions of the PISA Mathematics Framework and incorporates the recommendations of the Mathematics Strategic Advisory Group convened by OECD in 2017.

Definition of mathematical literacy

An understanding of mathematics is central to a young person's preparedness for participation in and contribution to modern society. A growing proportion of problems and situations encountered in daily life, including in professional contexts, require some level of understanding of mathematics before they can be properly understood and addressed. Mathematics is a critical tool for young people as they confront a wide range of issues and challenges in the various aspects of their lives.

It is therefore important to have an understanding of the degree to which young people emerging from school are adequately prepared to use mathematics to think about their lives, plan their futures, and reason about and solve meaningful problems related to a range of important issues in their lives. An assessment at age 15 provides countries with an early indication of how individuals may respond in later life to the diverse array of situations they will encounter that both involve mathematics and rely on mathematical reasoning (both deductive and inductive) and problem solving to make sense of.

As the basis for an international assessment of 15-year-old students, it is reasonable to ask: "What is important for citizens to know and be able to do in situations that involve mathematics?" More specifically, what does being mathematically competent mean for a 15-year-old, who may be emerging from school or preparing to pursue more specialised training for a career or university admission? It is important that the construct of mathematical literacy, which is used in this framework to denote *the capacity of individuals to reason mathematically and solve problems in a variety of 21st Century contexts*, not be perceived as synonymous with minimal, or low-level, knowledge and skills. Rather, it is intended to describe the capacities of individuals to *reason mathematically and use mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena*. This conception of mathematical literacy recognises the importance of students developing a sound understanding of a range of mathematical concepts and processes and realising the benefits of being engaged in real-world explorations that are supported by that mathematics. The construct of mathematical literacy, as defined for PISA, strongly emphasises the need to develop students' capacity to use mathematics in context, and it is important that they have rich experiences in their mathematics classrooms to accomplish this. This is as true for those 15-year-old students who are close to the end of their formal mathematics training, students who will continue with the formal study of mathematics, as well as out-of-school 15-year-olds.

Mathematical literacy transcends age boundaries. For example, OECD's Programme for the International Assessment of Adult Competencies (PIAAC) defines numeracy as *the ability to access, use, interpret, and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life.* The parallels between this definition for adults and the PISA 2022 definition of mathematical literacy for 15-year-olds are both marked and unsurprising.

The assessment of mathematical literacy for 15-year-olds must take into account relevant characteristics of these students; hence, there is a need to identify age-appropriate content, language and contexts. This framework distinguishes between broad categories of content that are important to mathematical literacy for individuals generally, and the specific content topics that are appropriate for 15-year-old students. Mathematical literacy is not an attribute that an individual either has or does not have. Rather, mathematical literacy is an attribute that is on a continuum, with some individuals being more mathematically literate than others – and with the potential for growth always present.

For the purposes of PISA 2022, mathematical literacy is defined as follows:

> *Mathematical literacy is an individual's capacity to reason mathematically and to formulate, employ, and interpret mathematics to solve problems in a variety of real-world contexts. It includes concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to know the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective 21st Century citizens.*

The PISA 2022 framework, when compared with the PISA 2003 and PISA 2012 frameworks, while appreciating and preserving the basic ideas of mathematical literacy developed there, acknowledges a number of shifts in the world of the student which in turn signal a shift on how to assess mathematical literacy in comparison to the approach used in previous frameworks. The trend is to move away from the need to perform basic calculations to a rapidly changing world driven by new technologies and trends in which citizens are creative and engaged, making judgements for themselves and the society in which they live.

As technology will play a growing role in the lives of students, the long-term trajectory of mathematical literacy should also encompass the synergistic and reciprocal relationship between mathematical thinking and computational thinking, introduced in (Wing, 2006[9]) as "the way computer scientists think" and regarded as a thought process entailed in formulating problems and designing their solutions in a form that can be executed by a computer, a human, or a combination of both (Wing, 2011[10]) (Cuny, Snyder and Wing, 2010[11]). The roles computational thinking play in mathematics include how specific mathematical topics interact with specific computing topics, and how mathematical reasoning complements computational thinking (Gadanidis, 2015[12]; Rambally, 2017[13]). For example, Pratt and Noss (2002[14]) discuss the use of a computational microworld for developing mathematical knowledge in the case of randomness and probability; Gadanidis et al. (2018[15]) propose an approach to engage young children with ideas of group theory, using a combination of hands-on and computational thinking tools. Hence, while mathematics education evolves in terms of the tools available and the potential ways to support students in exploring the powerful ideas of the discipline (Pei, Weintrop and Wilensky, 2018[16]), the thoughtful use of computational thinking tools and skill sets can deepen the learning of mathematics contents by creating effective learning conditions (Weintrop et al., 2016[17]). Moreover, computational thinking tools offer students a context in which they can reify abstract constructs (by exploring and engaging with maths concepts in a dynamic way) (Wing, 2008[18]), as well as express ideas in new ways and interact with concepts through media and new representational tools (Grover, 2018[19]; Niemelä et al., 2017[20]; Pei, Weintrop and Wilensky, 2018[16]; Resnick et al., 2009[21]).

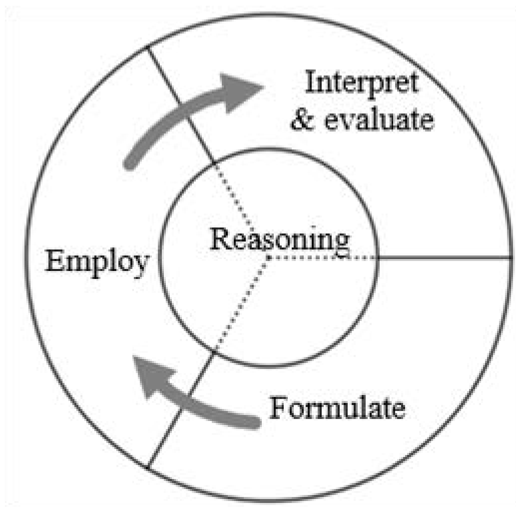
A view of mathematically literate individuals in PISA 2022

The focus of the language in the definition of mathematical literacy is on active engagement with mathematics to solve real-world problems in a variety of contexts, and is intended to encompass mathematical reasoning (both deductive and inductive) and problem solving using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena.

It is important to note that the definition of mathematical literacy not only focuses on the use of mathematics to solve real-world problems, but also identifies mathematical reasoning as a core aspect of being mathematically literate. The contribution that the PISA 2022 framework makes is to highlight the centrality of mathematical reasoning both to the problem-solving cycle and to mathematical literacy in general.

Figure 2.1 depicts the relationship between mathematical reasoning (both deductive and inductive) and problem solving as reflected in the mathematical modelling cycle of both the PISA 2003 and PISA 2012 framework.

Figure 2.1. Mathematical literacy: the relationship between mathematical reasoning and the problem solving (modelling) cycle



In order for students to be mathematically literate they must be able, first to use their mathematics content knowledge to recognise the mathematical nature of a situation (problem) especially those situations encountered in the real world and then to formulate it in mathematical terms. This transformation – from an ambiguous, messy, real-world situation to a well-defined mathematics problem – requires mathematical reasoning. Once the transformation is successfully made, the resulting mathematical problem needs to be solved using the mathematics concepts, algorithms and procedures taught in schools. However, it may require the making of strategic decisions about the selection of those tools and the order of their application – this is also a manifestation of mathematical reasoning. Finally, the PISA definition reminds us of the need for the student to evaluate the mathematical solution by interpreting the results within the original real-world situation. Additionally, students should also possess and be able to demonstrate computational thinking skills as part of their problem-solving practice. These computational thinking skills which are applied in formulating, employing, evaluating and reasoning include pattern recognition, decomposition, determining which (if any) computing tools could be employed in the analysing or solving the problem, and defining algorithms as part of a detailed solution.

Although mathematical reasoning and solving real-world problems overlap, there is an aspect to mathematical reasoning which goes beyond solving practical problems. Mathematical reasoning is also a way of evaluating and making arguments, evaluating interpretations and inferences related to statements (e.g. in public policy debates etc.) and problem solutions that are, by their quantitative nature, best understood mathematically.

Mathematical literacy therefore comprises two related aspects: *mathematical reasoning* and *problem solving*. *Mathematical literacy* plays an important role in being able to use mathematics to *solve real-world problems*. In addition, mathematical reasoning (both deductive and inductive) also goes beyond solving real-world problems to include the making of informed judgements about that important family of societal issues which can be addressed mathematically. It also includes making judgements about the validity of information that bombards individuals by means of considering their quantitative and logical, implications. It is here where mathematical reasoning also contributes to the development of a select set of 21st Century skills (discussed elsewhere in the framework).

The outer circle of Figure 2.2 shows that mathematical literacy takes place in the context of a challenge or problem that arises in the real world.

Figure 2.2. PISA 2022: The relationship between mathematical reasoning, the problem solving (modelling) cycle, mathematical contents, context and selected 21st Century skills

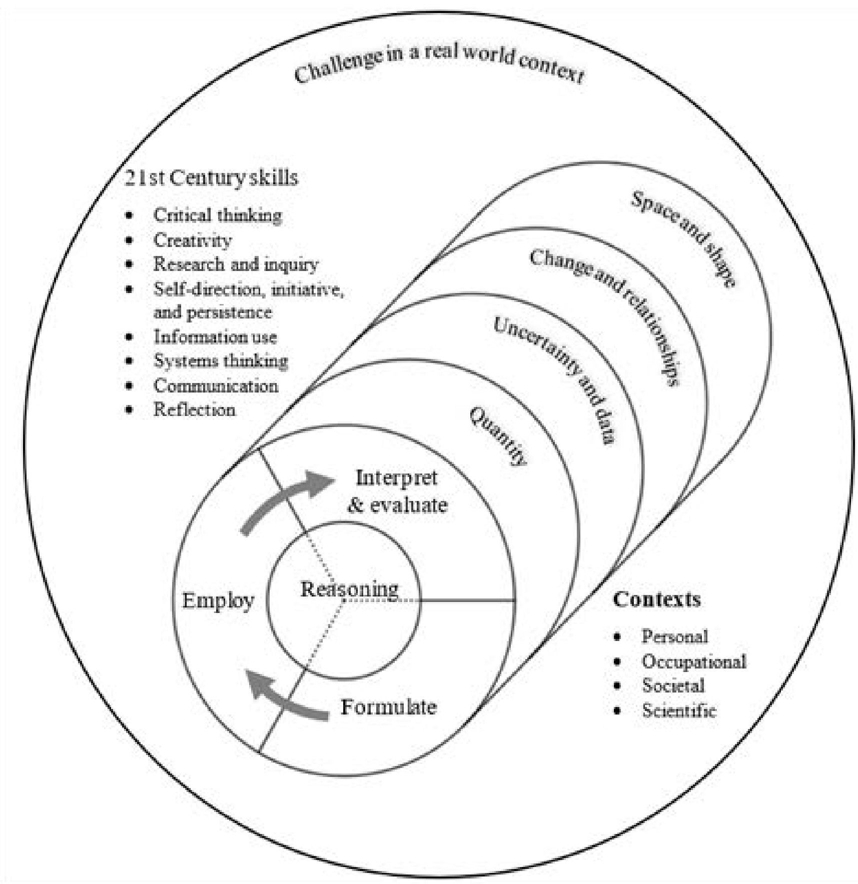


Figure 2.2 also depicts the relationship between mathematical literacy as depicted in Figure 2.1 and: the mathematical contents domains in which mathematical literacy is applied; the problem contexts and the selected 21st Century skills that are both supportive of and developed through mathematical literacy.

These categories of mathematics content include: quantity, uncertainty and data, change and relationships, and space and shape. It is these categories of mathematics content knowledge which students must draw on to reason, to formulate the problem (by transforming the real world situation into a mathematical problem situation), to solve the mathematical problem once formulated, and to interpret and evaluate the solution determined.

As in the previous frameworks, the four context areas that PISA continues to use to define real-world situations are personal, occupational, societal and scientific. The context may be of a personal nature, involving problems or challenges that might confront an individual or one's family or peer group. The problem might instead be set in a societal context (focusing on one's community – whether it be local, national or global), an occupational context (centred on the world of work), or a scientific context (relating to the application of mathematics to the natural and technological world).

Included for the first time in the PISA 2022 framework (and depicted in Figure 2.2) are selected 21st Century skills that mathematical literacy both relies on and develops. 21st Century skills are discussed in greater detail in the next section of this framework. For now, it should be stressed that while contexts (personal, societal, occupational and scientific) influence the development of test items, there is no expectation that items will be deliberately developed to incorporate or address 21st Century skills. Instead, the expectation is that by responding to the spirit of the framework and in line with the definition of mathematical literacy, the 21st Century skills that have been identified will be incorporated in the items.

The language of the definition and the representation in Figure 2.1 and Figure 2.2 retain and integrate the notion of mathematical modelling, which has historically been a cornerstone of the PISA framework for mathematics e.g. (OECD, 2004[6]; OECD, 2013[7]). The modelling cycle (formulate, employ, interpret and evaluate) is a central aspect of the PISA conception of mathematically literate students; however, it is often not necessary to engage in every stage of the modelling cycle, especially in the context of an assessment (Galbraith, Henn and Niss, 2007[22]). It is often the case that significant parts of the mathematical modelling cycle have been undertaken by others, and the end user carries out some of the steps of the modelling cycle, but not all of them. For example, in some cases, mathematical representations, such as graphs or equations, are given that can be directly manipulated in order to answer some question or to draw some conclusion. In other cases, students may be using a computer simulation to explore the impact of variable change in a system or environment. For this reason, many PISA items involve only parts of the modelling cycle. In reality, the problem solver may also sometimes oscillate between the processes, returning to revisit earlier decisions and assumptions. Each of the processes may present considerable challenges, and several iterations around the whole cycle may be required.

In particular, the verbs 'formulate', 'employ' and 'interpret' point to the three processes in which students as active problem solvers will engage. Formulating situations mathematically involves applying mathematical reasoning (both deductive and inductive) in identifying opportunities to apply and use mathematics – seeing that mathematics can be applied to understand or resolve a particular problem or challenge presented. It includes being able to take a situation as presented and transform it into a form amenable to mathematical treatment, providing mathematical structure and representations, identifying variables and making simplifying assumptions to help solve the problem or meet the challenge. Employing mathematics involves applying mathematical reasoning while using mathematical concepts, procedures, facts and tools to derive a mathematical solution. It includes performing calculations, manipulating algebraic expressions and equations or other mathematical models, analysing information in a mathematical manner from mathematical diagrams and graphs, developing mathematical descriptions and explanations and using mathematical tools to solve problems. Interpreting mathematics involves reflecting upon mathematical solutions or results and interpreting them in the context of a problem or challenge. It involves applying mathematical reasoning to evaluate mathematical solutions in relation to the context of the problem and determining whether the results are reasonable and make sense in the situation; determining also what to highlight when explaining the solution.

Included for the first time in the PISA 2022 framework is an appreciation of the intersection between mathematical and computational thinking engendering a similar set of perspectives, thought processes and mental models that learners need to succeed in an increasingly technological world. A set of constituent practices positioned under the computational thinking umbrella (namely abstraction, algorithmic thinking, automation, decomposition and generalisation) are also central to both mathematical reasoning and problem-solving processes. The nature of computational thinking within mathematics is conceptualised as defining and elaborating mathematical knowledge that can be expressed by programming, allowing students to dynamically model mathematical concepts and relationships. A taxonomy of computational thinking practices geared specifically towards mathematics and science learning entails data practices, modelling and simulation practices, computational problem-solving practices, and systems thinking practices (Weintrop et al., 2016[17]). The combination of mathematical and computational thinking not only becomes essential to effectively support the development of students' conceptual understanding of the mathematical domain, but also to develop their computational thinking concepts and skills, giving learners a more realistic view of how mathematics is practiced in the professional world and used in the real-world and, in turn, better prepares them for pursuing careers in related fields (Basu et al., 2016[23]; Benton et al., 2017[24]; Pei, Weintrop and Wilensky, 2018[16]; Beheshti et al., 2017[25]).

An explicit link to a variety of contexts for problems in PISA 2022

The reference to 'a variety of real-world contexts' in the definition of mathematical literacy recognises that the 21st Century citizen is a consumer of quantitative, sometimes statistical, arguments. The reference is intended as a way to link to the specific contexts that are described and exemplified more fully later in this framework. The specific contexts themselves are not so important, but the four categories selected for use here (personal, occupational, societal and scientific) reflect a wide range of situations in which individuals may meet mathematical opportunities. The definition also acknowledges that mathematical literacy helps individuals to recognise the role that mathematics plays in the world and to make the kinds of well-founded judgements and decisions required of constructive, engaged and reflective citizens faced with messages and arguments of the form: "a study found that on average...", "a survey shows a big drop in....", "certain scientists claim that population growth will outpace food production in *x* years …" etc.

A visible role for mathematical tools, including technology, in PISA 2022

The definition of mathematical literacy explicitly includes the use of mathematical tools. These tools include a variety of physical and digital equipment, software and calculation devices. Computer-based mathematical tools are in common use in workplaces of the 21st century, and will be increasingly more prevalent as the century progresses both in the workplace and in society generally. The nature of day-to-day and work-related problems and the demands on individuals to be able to employ mathematical reasoning (both deductive and inductive) in situations where computational tools are present has expanded with these new opportunities – creating enhanced expectations for mathematical literacy.

Since the 2015 cycle, computer-based assessment (CBA) has been the primary mode of testing, although an equivalent paper-based instrument is available for those countries who chose not to test their students by computer. The 2015 and 2018 mathematical literacy assessments did not exploit the opportunities that the computer provides.

Computer-Based Assessment of Mathematics (CBAM) will be the format of the mathematical literacy from 2022. Although the option of a paper-based assessment will remain for countries who want to continue in that way, the CBAM will exploit the opportunities of the CBAM. The opportunities that this transition creates are discussed in greater detail later in the framework.

Organisation of the domain

The PISA mathematics framework defines the domain of mathematics for the PISA survey and describes an approach to the assessment of the mathematical literacy of 15-year-olds. That is, PISA assesses the extent to which 15-year-old students can reason mathematically and handle mathematics adeptly when confronted with situations and problems – the majority of which are presented in real-world contexts.

For purposes of the assessment, the PISA 2022 definition of mathematical literacy can be analysed in terms of three interrelated aspects (see Figure 2.2):

- mathematical reasoning (both deductive and inductive) and problem solving (which includes the mathematical processes that describe what individuals do to connect the context of the problem with mathematics and thus solve the problem);
- the mathematical content that is targeted for use in the assessment items;
- the contexts in which the assessment items are located coupled with selected[2] 21st Century skills that support and are developed by mathematical literacy.

The following sections elaborate these aspects to support understanding and to provide guidance to the test developers. In highlighting these aspects of the domain, the PISA 2022 Mathematics Framework helps to ensure that assessment items developed for the survey reflect a range of mathematical reasoning and problem solving, content, and contexts and 21st Century skills, so that, considered as a whole, the set of assessment items effectively operationalises what this framework defines as mathematical literacy. Several questions, based on the PISA 2022 definition of mathematical literacy lie behind the organisation of this section of the framework. They are:

- What do individuals engage in when reasoning mathematically and solving contextual mathematical problems?
- What mathematical content knowledge can we expect of individuals – and of 15-year-old students in particular?
- In what context is mathematical literacy able to be both observed and assessed and how do these interact with the identified 21st Century skills?

Mathematical reasoning and problem-solving processes

Mathematical reasoning

Mathematical reasoning (both deductive and inductive) involves evaluating situations, selecting strategies, drawing logical conclusions, developing and describing solutions, and recognising how those solutions can be applied. Students reason mathematically when they:

- identify, recognise, organise, connect, and represent;
- construct, abstract, evaluate, deduce, justify, explain, and defend;
- interpret, make judgements, critique, refute, and qualify.

The ability to reason logically and to present arguments in honest and convincing ways is a skill that is becoming increasingly important in today's world. Mathematics is a science about well-defined objects and notions which can be analysed and transformed in different ways using 'mathematical reasoning' to obtain conclusions about which we are certain. Through mathematics, students learn that using appropriate reasoning they can reach results and conclusions which they can trust to be true. Further, those conclusions are logical and objective, and hence impartial, without any need for validation by an external authority. This kind of reasoning which is useful far beyond mathematics, can be learned and practiced most effectively within mathematics.

Two aspects of mathematical reasoning are especially important in today's world and in defining the PISA items. One is deduction from clear assumptions (deductive reasoning), which is a characteristic feature of mathematical process. The usefulness of this ability has already been stressed. The second important dimension is statistical and probabilistic (inductive) reasoning. At the logical level, there is these days frequent confusion in the minds of individuals between the possible and the probable, leading many to fall prey to conspiracy theories or fake news. From a technical perspective, today's world is increasingly complex and its multiple dimensions are represented by terabytes of data. Making sense of these data is one of the biggest challenges that humanity will face in the future. Our students should be familiarised with the nature of such data and making informed decisions in the context of variation and uncertainty.

Mathematical reasoning (both deductive and inductive), enabled by some key understandings that undergird school mathematics, is the core of mathematical literacy. Included among these key understandings are:

- understanding quantity, number systems and their algebraic properties;
- appreciating the power of abstraction and symbolic representation;
- seeing mathematical structures and their regularities;
- recognising functional relationships between quantities;
- using mathematical modelling as a lens onto the real world (e.g. those arising in the physical, biological, social, economic, and behavioural sciences);
- understanding variation as the heart of statistics.

The description of each of these that follows provides an overview of the understanding and how it supports reasoning. While the descriptions may appear abstract, the intention is not for them to be treated in an abstract way in the PISA assessment. The message that the descriptions should convey is how these ideas surface throughout school mathematics and how, by reinforcing their occurrence in teaching we support students to realise how they can be applied in new and different contexts.

Understanding quantity, number systems and their algebraic properties

The basic notion of quantity may be the most pervasive and essential mathematical aspect of engaging with, and functioning in, the world (OECD, 2017, p. 18[26]). At the most basic level it deals with the useful ability to compare cardinalities of sets of objects. The ability to count usually involves rather small sets – in most languages, only a small subset of numbers have names. When we assess larger sets, we engage in more complex operations of estimating, rounding and applying orders of magnitude. Counting is very closely related to another fundamental operation of classifying things, where the ordinal aspect of numbers emerges. Quantification of attributes of objects (measurement), relationships, situations and entities in the world is one of the most basic ways of conceptualising the surrounding world (OECD, 2017[26]).

Understanding quantity, number systems and their algebraic properties includes the basic concept of number, nested number systems (e.g., whole numbers to integers to rationals to reals), the arithmetic of numbers, and the algebraic properties that the systems enjoy. In particular, it is useful to understand how progressively more expansive systems of numbers enable the solution of progressively more complicated equations. This lays the foundation for enabling students to see more evidence of mathematics in the real world in as they learn more mathematics.

To use quantification efficiently, one has to be able to apply not just numbers, but the number systems. Numbers themselves are of limited relevance; what makes them into a powerful tool are the operations that we can perform with them. As such, a good understanding of the operations of numbers is the foundation of mathematical reasoning.

It is also important to understand matters of representation (as symbols involving numerals, as points on a number line, as geometric quantities, and by special symbols such as π) and how to move between them; the ways in which these representations are affected by number systems; the ways in which algebraic properties of these systems are relevant and matter for operating within the systems; and the significance of the additive and multiplicative identities, associativity, commutativity, and the distributive property of multiplication over addition. Algebraic principles undergird the place value system, allowing for economical expression of numbers and efficient approaches to operations on them. They are also central to number-line based operations with numbers, including work with additive inverses that are central to addition and subtraction of first integers, then rationals and finally reals.

The centrality of number as a key concept in all the other mathematical areas under consideration here and to mathematical reasoning itself, is undeniable. Students' grasp of the algebraic principles and properties first experienced through work with numbers is fundamental to their understanding of the concepts of secondary school algebra, along with their ability to become fluent in the manipulations of algebraic expressions necessary for solving equations, setting up models, graphing functions, and programming and making spreadsheet formulas. And in today's data-intensive world, facility with interpretation of patterns of numbers, comparison of patterns, and other numerical skills are evolving in importance.

A broad understanding of quantity and number systems supports reasoning in the real-world applications of mathematics envisaged by this framework.

Appreciating the power of abstraction and symbolic representation

The fundamental ideas of mathematics have arisen from human experience in the world and the need to provide coherence, order, and predictability to that experience. Many mathematical objects model reality, or at least reflect aspects of reality in some way. However, the essence of abstraction in mathematics is that it is a self-contained system, and mathematical objects derive their meaning from within that system. Abstraction involves deliberately and selectively attending to structural similarities between mathematical objects, and constructing relationships between those objects based on these similarities. In school mathematics, abstraction forms relationships between concrete objects, symbolic representations and operations including algorithms and mental models. This ability also plays a role in working with computational devices. The ability to create, manipulate, and draw meaning in working with abstractions in technological contexts in an important computational thinking skill.

For example, children begin to develop the concept of "circle" by experiencing specific objects that lead them to an informal understanding of circles as being "roundish". They might draw circles to represent these objects, noticing similarities between the drawings to generalise about "roundness" even though the circles are of different sizes. "Circle" becomes an abstract mathematical object when students start to "use" circles as objects in their work and more formally when it is defined as the locus of points equidistant from a fixed point in a two-dimensional plane.

Students use representations – whether text-based, symbolic, graphical, numerical, geometric or in programming code – to organise and communicate their mathematical thinking. Representations enable us to present mathematical ideas in a succinct way which, in turn, lead to efficient algorithms. Representations are also a core element of mathematical modelling, allowing students to abstract a simplified or idealised formulation of a real-world problem. Such structures are also important for interpreting and defining the behaviour of computational devices.

Having an appreciation of abstraction and symbolic representation supports reasoning in the real-world applications of mathematics envisaged by this framework by allowing students to move from the specific details of a situation to the more general features and to describe these in an efficient way.

Seeing mathematical structures and their regularities

When elementary students see: 5 + (3 + 8) some see a string of symbols indicating a computation to be performed in a certain order according to the rules of order of operations; others see a number added to the sum of two other numbers. The latter group are seeing structure; and because of that they don't need to be told about the order of operation, because if you want to add a number to a sum you first have to compute the sum.

Seeing structure continues to be important as students move to higher grades. A student who sees $f(x) = 5 + (x - 3)^2$ as saying that $f(x)$ is the sum of 5 and a square which is zero when x = 3 understands that the minimum of f is 5. This lays the foundation for functional thinking discussed in the next section.

Structure is intimately related to symbolic representation. The use of symbols is powerful, but only if they retain meaning for the symboliser, rather than becoming meaningless objects to be rearranged on a page. Seeing structure is a way of finding and remembering the meaning of an abstract representation. Such structures are also important for interpreting and defining the behaviour of computational devices. Being able to see structure is an important conceptual aid to procedural knowledge.

The examples above illustrate how seeing structure in abstract mathematical objects is a way of replacing parsing rules, which can be performed by a computer, with conceptual images of those objects that make their properties clear. An object held in the mind in such a way is subject to reasoning at a level that is higher than simple symbolic manipulation.

A robust sense of mathematical structure also supports modelling. When the objects under study are not abstract mathematical objects, but rather objects from the real world to be modelled by mathematics, then mathematical structure can guide the modelling. Students can also impose structure on non-mathematical objects in order to make them subject to mathematical analysis. An irregular shape can be approximated by simpler shapes whose area is known. A geometric pattern can be understood by hypothesising translational, rotational, or reflectional transformations and symmetry and abstractly extending the pattern into all of space. Statistical analysis is often a matter of imposing a structure on a set of data, for example by assuming it comes from a normal distribution or supposing that one variable is a linear function of another, but measured with normally distributed error.

Being able to see mathematical structures supports reasoning in the real-world applications of mathematics envisaged by this framework by allowing students to apply knowledge about situations or problems in one context to problems in another context that share a similar structure.

Recognising functional relationships between quantities

Students in elementary school encounter problems where they must find specific quantities. For example, how fast do you have to drive to get from Tucson to Phoenix, a distance of 180 km, in 1 hour and 40 minutes? Such problems have a specific answer: to drive 180 km in 1 hour and 40 minutes you must drive at 108 km per hour.

At some point students start to consider situations where quantities are variable, that is, where they can take on a range of values. For example, what is the relation between the distance driven, d, in kilometres, and time spent driving, t, in hours, if you drive at a constant speed of 108 *km* per hour? Such questions introduce functional relationships. In this case the relationship, expressed by the equation $d = 108t$, is a proportional relationship, the fundamental example and perhaps the most important for general knowledge.

Relationships between quantities can be expressed with equations, graphs, tables, or verbal descriptions. An important step in learning is to extract from these the notion of a function itself, as an abstract object of which these are representations. The essential elements of the concept are a domain, from which inputs are selected, a codomain, in which outputs lie, and a process for producing outputs from inputs.

Recognising the functional relationships between the variables in the real-world applications of mathematics envisaged by this framework supports reasoning by allowing students to focus on how the interdependence of and interaction between the variables impacts on the situation.

Using mathematical modelling as a lens onto the real world

Models represent a conceptualisation of phenomena. Models are simplifications of reality that fore- ground certain features of a phenomenon while approximating or ignoring other features. As such, ‘‘all models are wrong, but some are useful’’ (Box and Draper, 1987, p. 424[27]). The usefulness of a model comes from its explanatory and/or predictive power (Weintrop et al., 2016[17]). Models are, in that sense, abstractions of reality. A model may present a conceptualisation that is understood to be an approximation or working hypothesis concerning the object phenomenon or it may be an intentional simplification. Mathematical models are formulated in mathematical language and use a wide variety of mathematical tools and results (e.g., from arithmetic, algebra, geometry, etc.). As such, they are used as ways of precisely defining the conceptualisation or theory of a phenomenon, for analysing and evaluating data (does the model fit the data?), and for making predictions. Models can be operated – that is, made to run over time or with varying inputs, thus producing a simulation. When this is done, it is possible to make predictions, study consequences, and evaluate the adequacy and accuracy of the models. Throughout the modelling process cognisance needs to be taken of the real-world parameters that impact on the model and the solutions developed using the model.

Computer-based (or computational) models provide the ability to test hypothesis, generate data, introduce randomness and so on. Mathematical literacy includes the ability to understand, evaluate and draw meaning from computational models.

Using models in general and mathematical models in particular supports reasoning about the real-world applications of mathematics envisaged in this framework by encouraging students to focus on the most significant elements of the situations and in so doing to reduce the problem to its essence.

Understanding variation as the heart of statistics

In statistics accounting for variability is one, if not the central, defining element around which the discipline is based. In today’s world people often deal with these types of situations by merely ignoring the variation and as a result suggesting sweeping generalisations which are often misleading, if not wrong, and as a result very dangerous. Bias in the social science sense is usually created by not accounting for the sources and magnitudes of the variability in the trait under discussion.

Statistics is essentially about accounting for or modelling variation as measured by the variance or in the case of multiple variables the covariance matrix. This provides a probabilistic environment in which to understand various phenomena as well as to make critical decisions. Statistics is in many ways a search for patterns in a highly variable context: trying to find the single defining “truth” in the midst of a great deal of random noise. “Truth” is set in quotes as it is not the nature of truth that mathematics can deliver but an estimate of truth set in a probabilistic context, accompanied by an estimate of the error contained in the process. Ultimately, the decision maker is left with the dilemma of never knowing for certain what the truth is. The estimate that has been developed is, at best a range of possible values – the better the process, for example, the larger the sample of data, the narrower the range of possible values, although a range cannot be avoided. Some aspects of this have been present in previous PISA cycles, the growing significance contributes to the increased stress in this framework.

Understanding variation as a central feature of statistics supports reasoning about the real-world applications of mathematics envisaged in this framework in that students are encouraged to engage with data-based arguments with awareness of the limitations of the conclusions that can be drawn.

Problem solving

The definition of mathematical literacy refers to an individual's capacity to formulate, employ, and interpret (and evaluate) mathematics. These three words, formulate, employ and interpret, provide a useful and meaningful structure for organising the mathematical processes that describe what individuals do to connect the context of a problem with the mathematics and solve the problem. Items in the 2022 PISA mathematics test will be assigned to either mathematical reasoning or one of three mathematical processes:

- formulating situations mathematically;
- employing mathematical concepts, facts and procedures;
- interpreting, applying and evaluating mathematical outcomes.

It is important for both policy makers and those engaged more closely in the day-to-day education of students to know how effectively students are able to engage in each of these elements of the problem solving model/cycle. *Formulating* indicates how effectively students are able to recognise and identify opportunities to use mathematics in problem situations and then provide the necessary mathematical structure needed to formulate that contextualised problem in a mathematical form. *Employing* refers to how well students are able to perform computations and manipulations and apply the concepts and facts that they know to arrive at a mathematical solution to a problem formulated mathematically. *Interpreting* (and *evaluating*) relates to how effectively students are able to reflect upon mathematical solutions or conclusions, interpret them in the context of the real-world problem and determine whether the result(s) or conclusion(s) are reasonable and/or useful. Students' facility at applying mathematics to problems and situations is dependent on skills inherent in all three of these stages, and an understanding of students' effectiveness in each category can help inform both policy-level discussions and decisions being made closer to the classroom level.

Moreover, encouraging students to experience mathematical problem-solving processes through computational thinking tools and practices encourage students to practice prediction, reflection and debugging skills (Brennan and Resnick, 2012[28]).

Formulating situations mathematically

The word *formulate* in the mathematical literacy definition refers to individuals being able to recognise and identify opportunities to use mathematics and then provide mathematical structure to a problem presented in some contextualised form. In the process of formulating situations mathematically, individuals determine where they can extract the essential mathematics to analyse, set up and solve the problem. They translate from a real-world setting to the domain of mathematics and provide the real-world problem with mathematical structure, representations and specificity. They reason about and make sense of constraints and assumptions in the problem. Specifically, this process of formulating situations mathematically includes activities such as the following:

- selecting an appropriate model from a list;[3]
- identifying the mathematical aspects of a problem situated in a real-world context and identifying the significant variables;
- recognising mathematical structure (including regularities, relationships, and patterns) in problems or situations;
- simplifying a situation or problem in order to make it amenable to mathematical analysis (for example by decomposing);
- identifying constraints and assumptions behind any mathematical modelling and simplifications gleaned from the context;

- representing a situation mathematically, using appropriate variables, symbols, diagrams, and standard models;
- representing a problem in a different way, including organising it according to mathematical concepts and making appropriate assumptions;
- understanding and explaining the relationships between the context-specific language of a problem and the symbolic and formal language needed to represent it mathematically;
- translating a problem into mathematical language or a representation;
- recognising aspects of a problem that correspond with known problems or mathematical concepts, facts or procedures;
- choosing among an array of and employing the most effective computing tool to portray a mathematical relationship inherent in a contextualised problem;
- creating an ordered series of (step-by-step) instructions for solving problems.

Employing mathematical concepts, facts and procedures

The word *employ* in the mathematical literacy definition refers to individuals being able to apply mathematical concepts, facts, procedures, and reasoning to solve mathematically formulated problems to obtain mathematical conclusions. In the process of employing mathematical concepts, facts and procedures to solve problems, individuals perform the mathematical procedures needed to derive results and find a mathematical solution (e.g. performing arithmetic computations, solving equations, making logical deductions from mathematical assumptions, performing symbolic manipulations, extracting mathematical information from tables and graphs, representing and manipulating shapes in space, and analysing data). They work on a model of the problem situation, establish regularities, identify connections between mathematical entities, and create mathematical arguments. Specifically, this process of employing mathematical concepts, facts and procedures includes activities such as:

- performing a simple calculation;[4] **
- drawing a simple conclusion; **
- selecting an appropriate strategy from a list; **
- devising and implementing strategies for finding mathematical solutions;
- using mathematical tools, including technology, to help find exact or approximate solutions;
- applying mathematical facts, rules, algorithms, and structures when finding solutions;
- manipulating numbers, graphical and statistical data and information, algebraic expressions and equations, and geometric representations;
- making mathematical diagrams, graphs, simulations, and constructions and extracting mathematical information from them;
- using and switching between different representations in the process of finding solutions;
- making generalisations and conjectures based on the results of applying mathematical procedures to find solutions;
- reflecting on mathematical arguments and explaining and justifying mathematical results;
- evaluating the significance of observed (or proposed) patterns and regularities in data.

Interpreting, applying and evaluating mathematical outcomes

The word *interpret* (and *evaluate*) used in the mathematical literacy definition focuses on the ability of individuals to reflect upon mathematical solutions, results or conclusions and interpret them in the context of the real-life problem that initiated the process. This involves translating mathematical solutions or reasoning back into the context of the problem and determining whether the results are reasonable and make sense in the context of the problem. *Interpreting, applying and evaluating mathematical outcomes* encompasses both the ‘interpret’ and ‘evaluate’ elements of the mathematical modelling cycle. Individuals engaged in this process may be called upon to construct and communicate explanations and arguments in the context of the problem, reflecting on both the modelling process and its results. Specifically, this process of interpreting, applying and evaluating mathematical outcomes includes activities such as:

- interpreting information presented in graphical form and/or diagrams;**[5]
- evaluating a mathematical outcome in terms of the context;**
- interpreting a mathematical result back into the real-world context;
- evaluating the reasonableness of a mathematical solution in the context of a real-world problem;
- understanding how the real world impacts the outcomes and calculations of a mathematical procedure or model in order to make contextual judgements about how the results should be adjusted or applied;
- explaining why a mathematical result or conclusion does, or does not, make sense given the context of a problem;
- understanding the extent and limits of mathematical concepts and mathematical solutions;
- critiquing and identifying the limits of the model used to solve a problem;
- using mathematical thinking and computational thinking to make predictions, to provide evidence for arguments, to test and compare proposed solutions.

Mathematical content knowledge

An understanding of mathematical content – and the ability to apply that knowledge to solving meaningful contextualised problems – is important for citizens in the modern world. That is, to reason mathematically and to solve problems and interpret situations in personal, occupational, societal and scientific contexts, there is a need to draw upon certain mathematical knowledge and understanding.

Since the goal of PISA is to assess mathematical literacy, an organisational structure for mathematical content knowledge is proposed that is based on mathematical phenomena that underlie broad classes of problems. Such an organisation for content is not new, as exemplified by two well-known publications: *On the Shoulders of Giants: New Approaches to Numeracy* (Steen, 1990[29]) and *Mathematics: The Science of Patterns* (Devlin, 1994[30]).

The following content categories (previously used in 2012) are again used in PISA 2022 to reflect both the mathematical phenomena that underlie broad classes of problems, the general structure of mathematics, and the major strands of typical school curricula. These four categories characterise the range of mathematical content that is central to the discipline and illustrate the broad areas of content used in the test items for PISA 2022 (which will include PISA-D items to increase opportunities at the lower end of the performance spectrum):

- change and relationships;
- space and shape;
- quantity;
- uncertainty and data.

With these four categories, the mathematical domain can be organised in a way that ensures a spread of items across the domain and focuses on important mathematical phenomena, while at the same time, avoiding too granular a classification that would prevent the analysis of rich and challenging mathematical problems based on real situations.

While categorisation by content category is important for item development, selection and reporting of the assessment results, it is important to note that some items could potentially be classified in more than one content category.

National school mathematics curricula are typically organised around content strands (most commonly: numbers, algebra, functions, geometry, and data handling) and detailed topic lists help to define clear expectations. These curricula are designed to equip students with knowledge and skills that address these same underlying mathematical phenomena that organise the PISA content. The outcome is that the range of content arising from organising it in the way that PISA does is closely aligned with the content that is typically found in national mathematics curricula. This framework lists a range of content topics appropriate for assessing the mathematical literacy of 15-year-old students, based on analyses of national standards from eleven countries.

The broad mathematical content categories and the more specific content topics appropriate for 15-year-old students described in this section reflect the level and breadth of content that is eligible for inclusion in the PISA 2022 assessment. Descriptions of each content category and the relevance of each to reasoning and solving meaningful problems are provided, followed by more specific definitions of the kinds of content that are appropriate for inclusion in an assessment of mathematical literacy of 15-year-old students and out-of-school youth.

Four topics have been identified for special emphasis in the PISA 2022 assessment. These topics are not new to the mathematics content categories. Instead, these are topics within the existing content categories that deserve special emphasis. In the work of Mahajan et al. ("PISA Mathematics 2022", (2016[31])) the four topics are presented not only as commonly encountered situations in adult life in general, but as the types of mathematics needed in the emerging new areas of the economy such as high-tech manufacturing etc. The four are: growth phenomena; geometric approximations; computer simulations; and conditional decision making. These topics should be approached in the test items in a way that is consistent with the experiences of 15-year-olds. Each topic is discussed with the discussion of the corresponding content category as follows:

- growth phenomena (change and relationships);
- geometric approximation (space and shape);
- computer simulations (quantity);
- conditional decision making (uncertainty and data).

Change and relationships

The natural and designed worlds display a multitude of temporary and permanent relationships among objects and circumstances, where changes occur within systems of interrelated objects or in circumstances where the elements influence one another. In many cases these changes occur over time, and in other cases changes in one object or quantity are related to changes in another. Some of these situations involve discrete change; others change continuously. Some relationships are of a permanent, or invariant, nature. Being more literate about change and relationships involves understanding fundamental types of change and recognising when they occur in order to use suitable mathematical models to describe and predict change. Mathematically this means modelling the change and the relationships with appropriate functions and equations, as well as creating, interpreting and translating among symbolic and graphical representations of relationships.

Change and relationships is evident in such diverse settings as growth of organisms, music, seasonal change and cycles, weather patterns, employment levels and economic conditions. Aspects of the traditional mathematical content of functions and algebra, including algebraic expressions, equations and inequalities, tabular and graphical representations, are central in describing, modelling and interpreting change phenomena. Computational tools provide a means to visualise and interact with change and relationships. Recognising how and when a computational device can augment and complement mathematical concepts is an important computational thinking skill.

Representations of data and relationships described using statistics are also used to portray and interpret change and relationships, and a firm grounding in the basics of number and units is also essential to defining and interpreting change and relationships. Some interesting relationships arise from geometric measurement, such as the way that changes in perimeter of a family of shapes might relate to changes in area, or the relationships among lengths of the sides of triangles.

Growth phenomena: Understanding the dangers of flu pandemics and bacterial outbreaks, as well as the threat of climate change, demand that people think not only in terms of linear relationships but recognise that such phenomena need non-linear (often exponential but also other) models. Linear relationships are common and are easy to recognise and understand but to assume linearity can be dangerous. A good example of linearity and one probably used by everyone is estimating the distance travelled in various amounts of time while travelling at a given speed. Such an application provides a reasonable estimate as long as the speed stays relatively constant. But with flu epidemics, for example, such a linear approach would grossly underestimate the number of people sick in 5 days after the initial outbreak. Here is where a basic understanding of non-linear (including quadratic and exponential) growth and how rapidly infections can spread given that the rate of change increases from day to day is critical. The spread of the Zika infection is an important example of exponential growth; recognising it as such helped medical personnel to understand the inherent threat and the need for fast action.

Identifying growth phenomena as a focal point of the change and relationships content category is not to signal that there is an expectation that participating students should have studied the exponential function and certainly the items will not require knowledge of the exponential function. Instead, the expectation is that there will be items that expect students to (a) recognise that not all growth is linear, (b) that non-linear growth has particular and profound implications on how we understand certain situations, and (c) appreciate the intuitive meaning of "exponential growth" as an extremely rapid rate of growth, for example in the earthquake scale, every increase by 1 unit on the Richter scale does not mean a proportional increase in its effect, but rather by 10, 100, and 1000 times etc.

Space and shape

The topic of space and shape encompasses a wide range of phenomena that are encountered everywhere in our visual and physical world: patterns, properties of objects, positions and orientations, representations of objects, decoding and encoding of visual information, navigation and dynamic interaction with real shapes as well as with representations, movement, displacement, and the ability to anticipate actions in space. Geometry serves as an essential foundation for space and shape, but the category extends beyond traditional geometry in content, meaning and method, drawing on elements of other mathematical areas such as spatial visualisation, measurement and algebra. For instance, shapes can change and a point can move along a locus, thus requiring function concepts. Measurement formulas are central in this area. The recognition, manipulation and interpretation of shapes in settings that call for tools ranging from dynamic geometry software to Global Positioning Systems (GPS), and to machine learning software are included in this content category.

PISA assumes that the understanding of a set of core concepts and skills is important to mathematical literacy relative to space and shape. Mathematical literacy in the area of space and shape involves a range of activities such as understanding perspective (for example in paintings), creating and reading maps, transforming shapes with and without technology, interpreting views of three-dimensional scenes from various perspectives and constructing representations of shapes.

Geometric approximations: Today's world is full of shapes that do not follow typical patterns of evenness or symmetry. Because simple formulas do not deal with irregularity, it has become more difficult to understand what we see and find the area or volume of the resulting structures. For example, finding the needed amount of carpeting in a building in which the apartments have acute angles together with narrow curves demands a different approach than would be the case with a typically rectangular room.

Identifying geometric approximations as a focal point of the space and shape content category signals the need for students to be able use their understanding of traditional space and shape phenomena in a range of typical situations.

Quantity

The notion of quantity may be the most pervasive and essential mathematical aspect of engaging with, and functioning in, our world. It incorporates the quantification of attributes of objects, relationships, situations and entities in the world, understanding various representations of those quantifications and judging interpretations and arguments based on quantity. To engage with the quantification of the world involves understanding measurements, counts, magnitudes, units, indicators, relative size and numerical trends and patterns. Aspects of quantitative reasoning – such as number sense, multiple representations of numbers, elegance in computation, mental calculation, estimation and assessment of reasonableness of results – are the essence of mathematical literacy relative to quantity.

Quantification is a primary method for describing and measuring a vast set of attributes of aspects of the world. It allows for the modelling of situations, for the examination of change and relationships, for the description and manipulation of space and shape, for organising and interpreting data and for the measurement and assessment of uncertainty. Thus, mathematical literacy in the area of quantity applies knowledge of number and number operations in a wide variety of settings.

Computer simulations: Both in mathematics and statistics there are problems that are not so easily addressed because the required mathematics are complex or involve a large number of factors all operating in the same system or because of ethical issues relating to the impact on living beings or their environment. Increasingly in today's world such problems are being approached using computer simulations driven by algorithms. In the illustrative example *savings simulation* the student uses a computer simulation as a tool in decision making. The computer simulation does the calculations for the student, leaving the student to plan, predict and solve problems based on the variables that they can control.

Identifying computer simulations as a focal point of the quantity content category signals that in the context the Computer-Based Assessment of Mathematics (CBAM) of PISA being used from 2022, there are a broad category of complex problems including budgeting and planning that students can analyse in terms of the variables of the problem using computer simulations provided as part of the test item.

Uncertainty and data

In science, technology and everyday life, variation and its associated uncertainty is a given. It is a phenomenon at the heart of the theory of probability and statistics. The uncertainty and data content category includes recognising the place of variation in the real world including, having a sense of the quantification of that variation, and acknowledging its uncertainty and error in related inferences. It also includes forming, interpreting and evaluating conclusions drawn in situations where uncertainty is present. The presentation and interpretation of data are key concepts in this category (Moore, 1997[32]).

Economic predictions, poll results, and weather forecasts all include measures of variation and uncertainty. There is variation in manufacturing processes, test scores and survey findings, and chance is fundamental to many recreational activities enjoyed by individuals. The traditional curricular areas of probability and statistics provide formal means of describing, modelling and interpreting a certain class of phenomena in which variation plays a central role, and for making corresponding stochastic inferences. In addition, knowledge of number and of aspects of algebra such as graphs and symbolic representation contribute to engaging in problem solving in this content category.

Conditional decision making: statistics provides a measure of the variation characteristic of much of what people encounter in their daily lives. That measure is the variance. When there is more than one variable, there is variation in each of the variables as well as co-variation characterising the relationships among the variables. These inter-relationships can often be represented in two-way tables that provide the basis for making conditional decisions (inferences). In a two-way table for two dichotomous variables (i.e. two variables with two possibilities each), there are four combinations. The two-way table (analysis of the situation) provides three types of percentages which, in turn, provide estimates of the corresponding probabilities. These include the probabilities of the four joint events, the two marginal, and the conditional probabilities which play the central role in what we have termed conditional decision making. The expectation for the PISA test items is that students will be able to read the relevant data from the table with a deep understanding for the meaning of the data that they are extracting.

In the illustrative example *Purchasing Decision* the student is presented with a summary of customer ratings for a product in an online store. Additionally, the student is provided with more a more detailed analysis of the reviews by the customers who provided 1- and 2-star ratings. This effect sets up a two-way table and the student is asked to demonstrate an understanding of the different probability estimates that the two-way table provides

Identifying conditional decisions making as a focal point of the uncertainty and data content category signals that students should be expected to appreciate how the formulation of the analysis in a model impacts the conclusions that can be dawn and that different assumptions/relationships may well result in different conclusions.

Content topics for guiding the assessment of mathematical literacy of 15-year-old students

To effectively understand and solve contextualised problems involving change and relationships; space and shape; quantity; and uncertainty and data requires drawing upon a variety of mathematical concepts, procedures, facts, and tools at an appropriate level of depth and sophistication. As an assessment of mathematical literacy, PISA strives to assess the levels and types of mathematics that are appropriate for 15-year-old students on a trajectory to become constructive, engaged and reflective 21st Century citizens able to make well-founded judgements and decisions. It is also the case that PISA, while not designed or intended to be a curriculum-driven assessment, strives to reflect the mathematics that students have likely had the opportunity to learn by the time they are 15 years old.

In the development of the PISA 2012 mathematical literacy framework, with an eye toward developing an assessment that is both forward-thinking yet reflective of the mathematics that 15-year-old students have likely had the opportunity to learn, analyses were conducted of a sample of desired learning outcomes from eleven countries to determine both what is being taught to students in classrooms around the world and what countries deem realistic and important preparation for students as they approach entry into the workplace or admission into a higher education institution. Based on commonalities identified in these analyses, coupled with the judgement of mathematics experts, content deemed appropriate for inclusion in the assessment of mathematical literacy of 15-year-old students on PISA 2012, and continued for PISA 2022, is described below.

For PISA 2022, four additional focus topics have been added to the list. The resulting lists is intended to be illustrative of the content topics included in PISA 2022 and not an exhaustive listing:

- *Growth phenomena*: Different types of linear and non-linear growth.
- *Geometric approximation*: Approximating the attributes and properties of irregular or unfamiliar shapes and objects by breaking these shapes and objects up into more familiar shapes and objects for which there are formulae and tools.

- *Computer simulations*: Exploring situations (that may include budgeting, planning, population distribution, disease spread, experimental probability, reaction time modelling etc.) in terms of the variables and the impact that these have on the outcome.
- *Conditional decision making*: Using basic principles of combinatorics and an understanding of inter-relationships between variables to interpret situations and make predictions.
- *Functions*: The concept of function, emphasising but not limited to linear functions, their properties, and a variety of descriptions and representations of them. Commonly used representations are verbal, symbolic, tabular and graphical.
- *Algebraic expressions*: Verbal interpretation of and manipulation with algebraic expressions, involving numbers, symbols, arithmetic operations, powers and simple roots.
- *Equations and inequalities*: Linear and related equations and inequalities, simple second-degree equations, and analytic and non-analytic solution methods.
- *Co-ordinate systems*: Representation and description of data, position and relationships.
- *Relationships within and among geometrical objects in two and three dimensions*: Static relationships such as algebraic connections among elements of figures (e.g. the Pythagorean theorem as defining the relationship between the lengths of the sides of a right triangle), relative position, similarity and congruence, and dynamic relationships involving transformation and motion of objects, as well as correspondences between two- and three-dimensional objects.
- *Measurement*: Quantification of features of and among shapes and objects, such as angle measures, distance, length, perimeter, circumference, area and volume.
- *Numbers and units*: Concepts, representations of numbers and number systems (including converting between number systems), including properties of integer and rational numbers, as well as quantities and units referring to phenomena such as time, money, weight, temperature, distance, area and volume, and derived quantities and their numerical description.
- *Arithmetic operations*: The nature and properties of these operations and related notational conventions.
- *Percents, ratios and proportions*: Numerical description of relative magnitude and the application of proportions and proportional reasoning to solve problems.
- *Counting principles*: Simple combinations.
- *Estimation*: Purpose-driven approximation of quantities and numerical expressions, including significant digits and rounding.
- *Data collection, representation and interpretation*: Nature, genesis and collection of various types of data, and the different ways to analyse, represent and interpret them.
- *Data variability and its description*: Concepts such as variability, distribution and central tendency of data sets, and ways to describe and interpret these in quantitative and graphical terms.
- *Samples and sampling*: Concepts of sampling and sampling from data populations, including simple inferences based on properties of samples including accuracy and precision.
- *Chance and probability*: Notion of random events, random variation and its representation, chance and frequency of events, and basic aspects of the concept of probability and conditional probability.

Contexts for the assessment items and selected 21st Century skills

The definition of mathematical literacy introduces two important considerations for the PISA assessment items. First, the definition makes it clear that mathematical literacy takes place in *real-world contexts*. Second, mathematical literacy *assists individuals to know the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective*

21st Century citizens. In this section we discuss how both real-world contexts and 21st Century skills impact on item development.

The *real-world context* nature of mathematical literacy is not unproblematic for PISA. Real-world contexts involve information which is communicated using text. The quantitative and statistical information that flows in the world and reaches citizens is communicated through printed or spoken text, e.g. media articles, press releases, blogs, social networks, advertisements etc. This printed and spoken text is used to present messages or arguments that may or may not involve numbers and/or graphs. Text is the main tool for communicating context, and it follows that text comprehension is a fundamental and pre-requisite skill for success in mathematical literacy. The challenge this creates for PISA and item development is not insignificant. On the one hand the assessment must present socially meaningful quantitative messages using rich text, on the other hand the comparative nature of the assessment, the many languages it is translated into and the wide range of text comprehension levels among participating 15-year-olds places limits on the richness of the text that can realistically be used. This challenge is discussed further in the section on item development.

Contexts

An important aspect of mathematical literacy is that mathematics is used to solve a problem set in a context. The context is the aspect of an individual's world in which the problems are placed. The choice of appropriate mathematical strategies and representations is often dependent on the context in which a problem arises, and by implication there is the need to utilise knowledge of the real-world context in developing the model. Being able to work within a context is widely appreciated to place additional demands on the problem solver (see Watson and Callingham, (2003[33]), for findings about statistics). For PISA, it is important that a wide variety of contexts are used. This offers the possibility of connecting with the broadest possible range of individual interests and with the range of situations in which individuals operate in the 21st Century.

In light of the number of countries participating in PISA 2022 and with that an increasing range of participants from low- and middle-income countries as well as the possibility of out-of-school 15-year-olds, it is important that item developers take great care to ensure that the contexts used for items are accessible to a very broad range of participants. In this regard it is also important that the reading load of the items remains modest so that the items continue to assess mathematical literacy.

For purposes of the PISA 2022 Mathematics Framework, the four context categories of the PISA 2012 framework have been retained and are used to inform assessment item development. It should be noted that while these contexts are intended to inform item development, there is no expectation that there will be reporting against these contexts.

Personal – Problems classified in the personal context category focus on activities of one's self, one's family or one's peer group. The kinds of contexts that may be considered personal include (but are not limited to) those involving food preparation, shopping, games, personal health, personal transportation, recreation, sports, travel, personal scheduling and personal finance.

Occupational – Problems classified in the occupational context category are centred on the world of work. Items categorised as occupational may involve (but are not limited to) such things as measuring, costing and ordering materials for building, payroll/accounting, quality control, scheduling/inventory, design/architecture and job-related decision making either with or without appropriate technology. Occupational contexts may relate to any level of the workforce, from unskilled work to the highest levels of professional work, although items in the PISA survey must be accessible to 15-year-old students.

Societal – Problems classified in the societal context category focus on one's community (whether local, national or global). They may involve (but are not limited to) such things as voting systems, public transport, government, public policies, demographics, advertising, health, entertainment, national statistics and economics. Although individuals are involved in all of these things in a personal way, in the societal context category, the focus of problems is on the community perspective.

Scientific – Problems classified in the scientific category relate to the application of mathematics to the natural world and issues and topics related to science and technology. Particular contexts might include (but are not limited to) such areas as weather or climate, ecology, medicine, space science, genetics, measurement and the world of mathematics itself. Items that are intra-mathematical, where all the elements involved belong in the world of mathematics, fall within the scientific context.

PISA assessment items are arranged in units that share stimulus material. It is therefore usually the case that all items in the same unit belong to the same context category. Exceptions do arise; for example, stimulus material may be examined from a personal point of view in one item and a societal point of view in another. When an item involves only mathematical constructs without reference to the contextual elements of the unit within which it is located, it is allocated to the context category of the unit. In the unusual case of a unit involving only mathematical constructs and being without reference to any context outside of mathematics, the unit is assigned to the scientific context category.

Using these context categories provides the basis for selecting a mix of item contexts and ensures that the assessment reflects a broad range of uses of mathematics, ranging from everyday personal uses to the scientific demands of global problems. Moreover, it is important that each context category be populated with assessment items having a broad range of item difficulties. Given that the major purpose of these context categories is to challenge students in a broad range of problem contexts, each category should contribute substantially to the measurement of mathematical literacy. It should not be the case that the difficulty level of assessment items representing one context category is systematically higher or lower than the difficulty level of assessment items in another category.

In identifying contexts that may be relevant, it is critical to keep in mind that a purpose of the assessment is to gauge the use of mathematical content knowledge and skills that students have acquired by age 15. Contexts for assessment items, therefore, are selected in light of relevance to students' interests and lives and the demands that will be placed upon them as they enter society as constructive, engaged and reflective citizens. National Project Managers from countries participating in the PISA survey are involved in judging the degree of such relevance.

21st Century skills

There is increased interest worldwide in what are called 21st Century skills and their possible inclusion in educational systems. The OECD has put out a publication focusing on such skills and has sponsored a research project entitled *The Future of Education and Skills: An OECD 2030 Framework* in which some 25 countries are involved in a cross-national study of curriculum including the incorporation of such skills. The project has as its central focus what the curriculum might look like in the future, focusing initially on mathematics and physical education.

Over the past 15 years or so a number of publications have sought to bring clarity to the discussion and consideration of 21st Century skills. A summary of key reports and their conceptualisation of 21st Century skills is provided in *PISA 2021 Mathematics: A Broadened Perspective* [EDU/PISA/GB(2017)17]. After careful analysis of these publications the authors recommended that a strong case can be made for the infusion of specific 21st Century skills into specific disciplines. For example, it will become increasingly important to teach students at school how to make reasonable arguments with appropriate justification. The arguments they make should be mathematically rigorous, based on sound theory and strong enough to withstand criticism, and yet, whenever possible, avoid referring to authorities (e.g. 'it says so on the internet'). This is part of the fundamental competence to make independent judgements and take responsibility for them (OECD, 2005[34]). In the social context it is not enough to be right; one must be able and ready to present arguments and to defend them. Learning mathematics, with its clarity of contexts and strong emphasis on logical reasoning and rigour at the appropriate level, is a perfect opportunity to practice and develop the ability for this kind of argumentation.

Similarly, in the modern era, it is critical to equip students with tools that they can use to defend themselves from lies and inferences that purport to be based on mathematical reasoning. Quite often some fluency in logical reasoning is sufficient; a lie usually hides some hidden contradiction. The alertness of young minds towards possible contradictions can be developed most easily in good classes of mathematics.

Using the logic of finding the intersection between generic 21st Century skills and related but subject-matter specific skills that are a natural part of the instruction related to that subject matter results in the following identified eight 21st Century skills for inclusion in the PISA 2022 assessment framework. They are:

- critical thinking;
- creativity;
- research and inquiry;
- self-direction, initiative, and persistence;
- information use;
- systems thinking;
- communication;
- reflection.

Assessing mathematical literacy

This section outlines the approach taken to implement the elements of the framework described in previous sections into the PISA survey for 2022. This includes the structure of the mathematics component of the PISA survey, the desired distribution of score points for mathematical reasoning and the processes of problem solving; the distribution of score points by content area; a discussion on the range of item difficulties; the structure of the survey instrument; the role of the computer-based assessment of mathematics; the design of the assessment items; and the reporting of levels of mathematical proficiency.

Structure of the PISA 2022 mathematics assessment

In accordance with the definition of mathematical literacy, assessment items used in any instruments that are developed as part of the PISA survey are set within a context. Items involve the application of important mathematical concepts, knowledge, understandings and skills (mathematical content knowledge) at the appropriate level for 15-year-old students, as described earlier. The framework is used to guide the structure and content of the assessment, and it is important that the survey instrument include an appropriate balance of items reflecting the components of the mathematical literacy framework.

Desired distribution of score points by mathematical reasoning and problem-solving process

Assessment items in the PISA 2022 mathematics survey can be assigned to either mathematical reasoning or one of three mathematical processes associated with mathematical problem solving. The goal in constructing the assessment is to achieve a balance that provides approximately equal weighting between the two processes that involve making a connection between the real world and the mathematical world (formulating and interpreting/evaluating) and mathematical reasoning and employing which call for students to be able to work on a mathematically formulated problem. While it is true that mathematical reasoning can be observed within the process of formulating, interpreting and employing items will only contribute to one domain.

Table 2.1. Approximate distribution of score points by domain for PISA 2022

		Percentage of score points in PISA 2022
Mathematical reasoning		Approximately 25
Mathematical problem solving	Formulating situations mathematically	Approximately 25
	Employing mathematical concepts, facts and procedures	Approximately 25
	Interpreting, applying and evaluating mathematical outcomes	Approximately 25
TOTAL		100

It is important to note that items in each process category should have a range of difficulty and mathematical demand. This is further addressed in the table of demands for mathematical reasoning and each of the problem solving processes.

Desired distribution of score points by content category

PISA mathematics items are selected to reflect the mathematical content knowledge described earlier in this framework. The trend items selected for PISA 2022 will be distributed across the four content categories, as shown in Table 2.2. The goal in constructing the survey is a distribution of items with respect to content category that provides as balanced a distribution of score points as possible, since all of these domains are important for constructive, engaged and reflective citizens.

Table 2.2. Approximate distribution of score points by content category for PISA 2022

Content category	Percentage of score points in PISA 2022
Change and relationships	Approximately 25
Space and shape	Approximately 25
Quantity	Approximately 25
Uncertainty and data	Approximately 25
TOTAL	100

It is important to note that items in each content category should have a range of difficulty and mathematical demand.

A range of item difficulties

The PISA 2022 mathematical literacy survey includes items with a wide range of difficulties, paralleling the range of abilities of 15-year-old students. It includes items that are challenging for the most able students and items that are suitable for the least able students assessed on mathematical literacy. From a psychometric perspective, a survey that is designed to measure a particular cohort of individuals is most effective and efficient when the difficulty of assessment items matches the ability of the measured subjects. Furthermore, the described proficiency scales that are used as a central part of the reporting of PISA outcomes can only include useful details for all students if the items from which the proficiency descriptions are drawn span the range of abilities described.

Table 2.3 describes the range of actions that are expected of students for mathematical reasoning and each of the problem-solving processes. These lists describe the actions that the items will demand of students. For each category there are a number of items marked with "**" to denote the actions that are expected of the students that will perform at levels 1a, 1b and 1c as well as level 2 of the proficiency scale. Item developers will need to ensure that there are sufficient items at the lower end of the performance scale to allow students at these levels to be able to show what they are capable of.

In order to gain useful information for the new lower levels, 1b and 1c, it is vital that context and language do not interfere with the mathematics being assessed. To this end, the context and language must be carefully considered. That said, the items must still be interesting to avoid the possibility that students will simply not attempt the items because it holds no interest.

The context for both 1b and 1c level items should be situations that students encounter on a daily basis. Examples of these contexts may include money, temperature, food, time, date, weight, size and distance. All items should be concrete and not abstract. The focus of the item should be mathematical only. The understanding of the context should not interfere with the performance of the item.

Equally important, it is to have all items formulated in the simplest possible terms. Sentences should be short and direct. Compound sentences, compound nouns and conditional sentences should be avoided. Vocabulary used in the items must be carefully examined to ensure that students will have a clear understanding of what is being required. In addition, special care will be given to ensure that no extra difficulty is added due to a heavy text load or by a context that is unfamiliar to students based on their cultural background.

Items designed for Level 1c should only ask for a single step or operation. However, it is important to note that a single step or operation is not limited to an arithmetical step. This step might be demonstrated by making a selection or identifying some information. Both mathematical reasoning and all of the problem solving processes should be used to measure the mathematical literacy capabilities of students at Levels 1b and 1c.

Table 2.3. Expected student actions for mathematical reasoning and each of the problem-solving processes

Reasoning
** Draw a simple conclusion
** Select an appropriate justification
** Explain why a mathematical result or conclusion does, or does not, make sense given the context of a problem
Represent a problem in a different way, including organising it according to mathematical concepts and making appropriate assumptions
Utilise definitions, rules and formal systems as well as employing algorithms and computational thinking
Explain and defend a justification for the identified or devised representation of a real-world situation
Explain or defend a justification for the processes and procedures or simulations used to determine a mathematical result or solution
Identify the limits of the model used to solve a problem
Understand definitions, rules and formal systems as well as employing algorithms and computational reasoning
Provide a justification for the identified or devised representation of a real-world situation
Provide a justification for the processes and procedures used to determine a mathematical result or solution
Reflect on mathematical arguments, explaining and justifying the mathematical result
Critique the limits of the model used to solve a problem
Interpret a mathematical result back into the real-world context in order to explain the meaning of the results
Explain the relationships between the context-specific language of a problem and the symbolic and formal language needed to represent it mathematically
Reflect on mathematical arguments, explaining and justifying the mathematical result
Reflect on mathematical solutions and create explanations and arguments that support, refute or qualify a mathematical solution to a contextualised problem
Analyse similarities and differences between a computational model and the mathematical problem that it is modelling
Explain how a simple algorithm works and to detect and correct errors in algorithms and programmes

Formulating	Employing	Interpreting
** Select a mathematical description or a representation that describes a problem	** Perform a simple calculation	**Interpret a mathematical result back into the real world context
** Identify the key variables in a model	** Select an appropriate strategy from a list	** Identify whether a mathematical result or conclusion does, or does not, make sense given the context of a problem
** Select a representation appropriate to the problem context	** Implement a given strategy to determine a mathematical solution	** Identify the limits of the model used to solve a problem
Read, decode and make sense of statements, questions, tasks, objects or images to create a model of the situation	** Make mathematical diagrams, graphs, constructions or computing artifacts	Use mathematical tools or computer simulations to ascertain the reasonableness of a mathematical solution and any limits and constraints on that solution, given the context of the problem
Recognise mathematical structure (including regularities, relationships, and patterns) in problems or situations	Understand and utilise constructs based on definitions, rules and formal systems including employing familiar algorithms	Interpret mathematical outcomes in a variety of formats in relation to a situation or use; compare or evaluate two or more representations in relation to a situation
Identify and describe the mathematical aspects of a real-world problem situation including identifying the significant variables	Develop mathematical diagrams, graphs, constructions or computing artifacts and extracting mathematical information from them	Use knowledge of how the real world impacts the outcomes and calculations of a mathematical procedure or model in order to make contextual judgements about how the results should be adjusted or applied
Simplify or decompose a situation or problem in order to make it amenable to mathematical analysis	Manipulate numbers, graphical and statistical data and information, algebraic expressions and equations, and geometric representations	Construct and communicate explanations and arguments in the context of the problem
Recognise aspects of a problem that correspond with known problems or mathematical concepts, facts or procedures	Articulate a solution, showing and/or summarising and presenting intermediate mathematical results	Recognise [demonstrate, interpret, explain] the extent and limits of mathematical concepts and mathematical solutions
Translate a problem into a standard mathematical representation or algorithm	Use mathematical tools, including technology, simulations and computational thinking, to help find exact or approximate solutions	Understand the relationship between the context of the problem and representation of the mathematical solution. Use this understanding to help interpret the solution in context and gauge the feasibility and possible limitations of the solution
Use mathematical tools (using appropriate variables, symbols, diagrams) to describe the mathematical structures and/or relationships in a problem	Make sense of, relate and use a variety of representations when interacting with a problem	
Apply mathematical tools and computing tool to portray mathematical relationships	Switch between different representations in the process of finding solutions	
Identify the constraints, assumptions simplifications in a mathematical model	Use a multi-step procedure leading to a mathematical solution, conclusion or generalisation	
	Use an understanding of the context to guide or expedite the mathematical solving process, e.g. working to a context-appropriate level of accuracy	
	Make generalisations based on the results of applying mathematical procedures to find solutions	

Note: *Table 2.3* is a reformulation of the figure used in previous frameworks to link mathematical processes with mathematical capabilities. All of the examples and illustrations from that figure are included in this reformulation.

Computer-based assessment of mathematics

The main mode of delivery for PISA 2022 will be the computer-based assessment of mathematics (CBAM). The transition has been anticipated with both the 2015 and 2018 studies moving to computer-based delivery. In order to maintain trends across the studies, both the 2015 and 2018 assessments were computer neutral despite using a computer-based delivery mode. The transition to a full CBAM in 2022 provides a range of opportunities to develop the assessment of mathematical literacy to be better aligned with the evolving nature of mathematics in the modern world, while ensuring backward trends to previous cycles. These opportunities include new item formats (e.g. drag and drop); presenting students with real-world data (such as large, sortable datasets); creating mathematical models or simulations that students can explore by changing the variable values; curve fitting and using the best fit curve to make predictions. In addition to a wider range of question types and mathematical opportunities that the CBAM provides, it also allows for adaptive assessment.

The adaptive assessment capability of the CBAM, which was previously implemented in the PISA reading assessment, provides the opportunity of better describing what it is that students at both ends of the performance spectrum are able to do. By providing students with increasing individualised combinations of test units according to their responses and scores to the early units that they respond to, increasingly detailed information on the performance characteristics of students at both ends of the performance scale is generated.

Making use of enhancements offered by computer technology results in assessment items that are more engaging to students, more visually appealing, and easier to understand. For example, students may be presented with a moving stimulus, representations of three-dimensional objects that can be rotated or more flexible access to relevant information. New item formats, such as those calling for students to ‘drag and drop’ information or use ‘hot spots’ on an image, are designed to engage students, permit a wider range of response types and give a more rounded picture of mathematical literacy. A key challenge is to ensure that these items continue to assess *mathematical literacy* and that interference from domain irrelevant dimensions is kept to a minimum.

Investigations show that the mathematical demands of work increasingly occur in the presence of electronic technology so that mathematical literacy and computer use are melded together (Hoyles et al., 2002[35]). For employees at all levels of the workplace, there is now an interdependency between mathematical literacy and the use of computer technology. A key challenge is to distinguish the mathematical demands of a PISA computer-based item from demands unrelated to mathematical competence, such as the information and communications technology (ICT) demands of the item, and the presentation format. Solving PISA items on a computer rather than on paper moves PISA into the reality and the demands of the 21st Century.

Questions that seem well suited to the CBAM and the evolving nature of mathematical literacy include:

- Simulation in which a mathematical model has been established and students can change the variable values to explore the impact of the variables to create “an optimal solution”.
- Fitting a curve (by selecting a curve from a limited set of curves provided) to a data set or a geometric image to determine the “best fit” and using the resulting best fit curve to determine the answer to a question about the situation.
- Budgeting situations (e.g. online store) in which the student must select combinations of products to meet achieve a range of objectives within a given budget.
- Purchase simulation in which the student selects from different loan and associates repayment options to purchase an item using a loan and meeting a budget. The challenge in the problem is to understand how the variables interact.
- Problems that include visual coding to achieve a given sequence of actions.

Notwithstanding the opportunities that the CBAM presents (described above), it is important that the CBAM remains focused on assessing mathematical literacy and does not shift to assessing ICT skills. Similarly, it is important that the simulations and other questions hinted at above do not become so “noisy” that the mathematical reasoning and problem-solving processes are lost.

The CBAM must also retain some of the paper version features for example the ability to revisit items already attempted – although in the context of adaptive testing this will of necessity be limited to the unit on which the student is working.

Design of the PISA 2022 mathematics items

Three item format types are used to assess mathematical literacy in PISA 2022: open constructed-response, closed constructed-response and selected-response (multiple-choice) items.

Open constructed-response items require a somewhat extended written response from a student. Such items also may ask the student to show the steps taken or to explain how the answer was reached. These items require trained experts to manually code student responses. To facilitate the adaptive assessment feature of the CBAM, it will be necessary to minimise the number of items that rely on trained experts to code the student responses.

Closed constructed-response items provide a more structured setting for presenting problem solutions, and they produce a student response that can be easily judged to be either correct or incorrect. Often student responses to questions of this type can be coded automatically. The most frequently used closed constructed-responses are single numbers.

Selected-response items require the choice of one or more responses from a number of response options. Responses to these questions can usually be automatically processed. About equal numbers of each of these item format types are being used to construct the survey instruments.

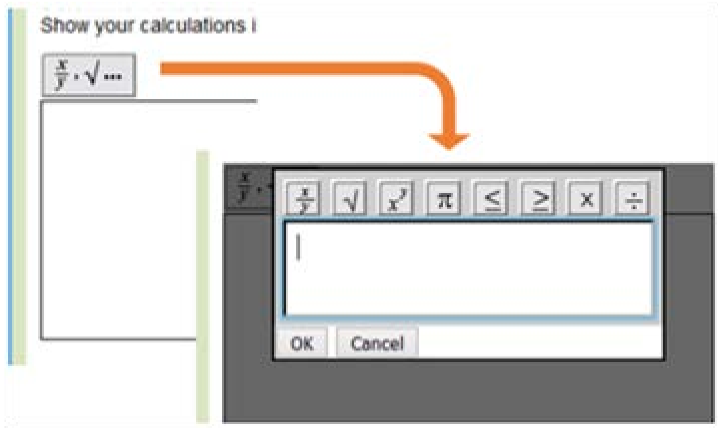
The PISA mathematics survey is composed of assessment *units* comprising written stimulus material and other information such as tables, charts, graphs or diagrams, plus one or more items that are linked to this common stimulus material. This format gives students the opportunity to become involved with a context or problem by responding to a series of related items.

Items selected for inclusion in the PISA survey represent a broad range of difficulties, to match the wide ability range of students participating in the assessment. In addition, all the major categories of the assessment (the content categories; mathematical reasoning and problem-solving process categories and the different context categories and 21st Century skills) are represented, to the degree possible, with items of a wide range of difficulties. Item difficulties are established as one of a number of measurement properties in an extensive field trial prior to item selection for the main PISA survey. Items are selected for inclusion in the PISA survey instruments based on their fit with framework categories and their measurement properties.

In addition, the level of reading required to successfully engage with an item is considered very carefully in item development and selection. A goal in item development is to make the wording of items as simple and direct as possible. Care is also taken to avoid item contexts that would create a cultural bias, and all choices are checked with national teams. Translation of the items into many languages is conducted very carefully, with extensive back-translation and other protocols.

PISA 2022 will include a tool that will allow students to provide typed constructed response answers and show their work as required for mathematical literacy. The tool allows students to enter both text and numbers. By clicking the appropriate button, students can enter a fraction, square root, or exponent. Additional symbols such as π and greater/less than signs are available, as are operators such as multiplication and division signs. An example is shown in Figure 2.3 below.

Figure 2.3. Example of the PISA 2022 editor tool



The suite of tools available to students is also expected to include a basic scientific calculator. Operators to be included are addition, subtraction, multiplication and division, as well as square root, pi, parentheses, exponent, square, fraction (y/x), inverse (1/x) and the calculator will be programmed to respect the standard order of operations.

Students taking the assessment on paper can have access to a hand-held calculator, as approved for use by 15-year-old students in their respective school systems.

Item scoring

Although the majority of the items are dichotomously scored (that is, responses are awarded either credit or no credit), the open constructed-response items can sometimes involve partial credit scoring, which allows responses to be assigned credit according to differing degrees of "correctness" of responses and or to the extent to which an item has been engaged with or not. It is anticipated that the need for partial credit scoring will be particularly significant for the mathematical reasoning items which will seldom involve the production of single number response but rather responses with one or more elements.

Reporting proficiency in mathematics

The outcomes of the PISA mathematics survey are reported in a number of ways. Estimates of overall mathematical proficiency are obtained for sampled students in each participating country, and a number of proficiency levels are defined. Descriptions of the degree of mathematical literacy typical of students in each level are also developed. For PISA 2022, the six proficiency levels reported for the overall PISA mathematics in previous cycles will be expanded as follows: Level 1 will be renamed Level 1a, and the table describing the proficiencies will be extended to include Levels 1b and 1c. These additional levels have been added to provide greater granularity of reporting in students performing at the lower end of the proficiency scale. In Table 2.4, summary descriptions of the eight proficiency levels on the mathematical literacy for the overall PISA mathematics scale in 2022 are presented.

Table 2.4. Summary descriptions of the eight proficiency levels on the mathematical literacy scale

Level	What students can typically do
6	At Level 6, students can work through abstract problems and demonstrate creativity and flexible thinking to develop solutions. For example, they can recognise when a procedure that is not specified in a task can be applied in a non-standard context or when demonstrating a deeper understanding of a mathematical concept is necessary as part of a justification. They can link different information sources and representations, including effectively using simulations or spreadsheets as part of their solution. Students at this level are capable of critical thinking and have a mastery of symbolic and formal mathematical operations and relationships that they use to clearly communicate their reasoning. They can reflect on the appropriateness of their actions with respect to their solution and the original situation.
5	At Level 5, students can develop and work with models for complex situations, identifying or imposing constraints, and specifying assumptions. They can apply systematic, well-planned problem-solving strategies for dealing with more challenging tasks, such as deciding how to develop an experiment, designing an optimal procedure, or working with more complex visualisations that are not given in the task. Students demonstrate an increased ability to solve problems whose solutions often require incorporating mathematical knowledge that is not explicitly stated in the task. Students at this level reflect on their work and consider mathematical results with respect to the real-world context.
4	At Level 4, students can work effectively with explicit models for complex concrete situations, sometimes involving two variables, as well as demonstrate an ability to work with undefined models that they derive using a more sophisticated computational-thinking approach. Students at this level begin to engage with aspects of critical thinking, such as evaluating the reasonableness of a result by making qualitative judgements when computations are not possible from the given information. They can select and integrate different representations of information, including symbolic or graphical, linking them directly to aspects of real-world situations. At this level, students can also construct and communicate explanations and arguments based on their interpretations, reasoning, and methodology.
3	At Level 3, students can devise solution strategies, including strategies that require sequential decision making or flexibility in understanding of familiar concepts. At this level, students begin using computational-thinking skills to develop their solution strategy. They are able to solve tasks that require performing several different but routine calculations that are not all clearly defined in the problem statement. They can use spatial visualisation as part of a solution strategy or determine how to use a simulation to gather data appropriate for the task. Students at this level can interpret and use representations based on different information sources and reason directly from them, including conditional decision making using a two-way table. They typically show some ability to handle percentages, fractions and decimal numbers, and to work with proportional relationships.
2	At Level 2, students can recognise situations where they need to design simple strategies to solve problems, including running straightforward simulations involving one variable as part of their solution strategy. They can extract relevant information from one or more sources that use slightly more complex modes of representation, such as two-way tables, charts, or two-dimensional representations of three-dimensional objects. Students at this level demonstrate a basic understanding of functional relationships and can solve problems involving simple ratios. They are capable of making literal interpretations of results.
1a	At Level 1a, students can answer questions involving simple contexts where all information needed is present, and the questions are clearly defined. Information may be presented in a variety of simple formats and students may need to work with two sources simultaneously to extract relevant information. They are able to carry out simple, routine procedures according to direct instructions in explicit situations, which may sometimes require multiple iterations of a routine procedure to solve a problem. They can perform actions that are obvious or that require very minimal synthesis of information, but in all instances the actions follow clearly from the given stimuli. Students at this level can employ basic algorithms, formulae, procedures, or conventions to solve problems that most often involve whole numbers.
1b	At Level 1b, students can respond to questions involving easy to understand contexts where all information needed is clearly given in a simple representation (i.e., tabular or graphic) and, as necessary, recognise when some information is extraneous and can be ignored with respect to the specific question being asked. They are able to perform simple calculations with whole numbers, which follow from clearly prescribed instructions, defined in short, syntactically simple text.
1c	At Level 1c, students can respond to questions involving easy to understand contexts where all relevant information is clearly given in a simple, familiar format (for example, a small table or picture) and defined in a very short, syntactically simple text. They are able to follow a clear instruction describing a single step or operation.

As well as the overall mathematics scale, additional described proficiency scales are developed after the field trial and are then reported. These additional scales are for mathematical reasoning and for the three processes of mathematical problem solving: *formulating situations mathematically; employing mathematical concepts, facts and procedures; and interpreting, applying and evaluating mathematical outcomes.*

Mathematical literacy and the background questionnaires

Since the first cycle of PISA, student and school context questionnaires have served two interrelated purposes in service of the broader goal of evaluating educational systems: first, the questionnaires provide a context through which to interpret the PISA results both within and between education systems. Second, the questionnaires aim to provide reliable and valid measurement of additional educational indicators, which can inform policy and research in their own right.

Since mathematical literacy is the major domain in the 2022 survey, the background questionnaires are expected to provide not only trend data for the constructs that continue to be assessed, but additionally to provide rich information on the innovations that are evident in the PISA 2022 mathematical literacy framework. In particular it is expected that mathematical literacy will feature prominently in the analysis of the domain-specific contextual constructs as well in a number of the different categories of policy focus that range from individual level variables such a demographics and social and emotional characteristics to school practices, policies and infrastructure (OECD, 2018[36]).

Two broad areas of students' attitudes towards mathematics that dispose them to productive engagement in mathematics were identified as being of potential interest as an adjunct to the PISA 2012 mathematics assessment. These are students' interest in mathematics and their willingness to engage in it. It is expected that these will continue to be a focus of the questionnaires in 2022.

Interest in mathematics has components related to present and future activity. Relevant questions focus on students' interest in mathematics at school, whether they see it as useful in real life as well as their intentions to undertake further study in mathematics and to participate in mathematics-oriented careers. There is international concern about this area, because in many participating countries there is a decline in the percentage of students who are choosing mathematics related future studies, whereas at the same time there is a growing need for graduates from these areas.

Students' willingness to do mathematics is concerned with the attitudes, emotions and self-related beliefs that dispose students to benefit, or prevent them from benefitting, from the mathematical literacy that they have achieved. Students who enjoy mathematical activity and feel confident to undertake it are more likely to use mathematics to think about the situations that they encounter in the various facets of their lives, inside and outside school. The constructs from the PISA survey that are relevant to this area include the emotions of enjoyment, confidence and (lack of) mathematics anxiety, and the self-related beliefs of self-concept and self-efficacy. An analysis of the subsequent progress of young Australians who scored poorly on PISA at age 15 found that those who "recognise the value of mathematics for their future success are more likely to achieve this success, and that includes being happy with many aspects of their personal lives as well as their futures and careers" (Hillman and Thomson, 2010, p. 31[37]). The study recommends that a focus on the practical applications of mathematics in everyday life may help improve the outlook for these low-achieving students.

The innovations evident in the PISA 2022 Mathematics Framework point to at least four areas in which the background questionnaires can provide rich data. These areas are: **mathematical reasoning**; **computational thinking** and the role of technology in both doing and teaching mathematics; the **four focal content areas**; and **21st Century skills in the context of mathematics**.

Mathematical reasoning

The PISA 2022 Mathematics Framework foregrounds mathematical reasoning enabled by some key understandings that undergird school mathematics (understanding quantity, number systems and their algebraic properties; appreciating the power of abstraction and symbolic representation; seeing mathematical structures and their regularities; recognising functional relationships between quantities; using mathematical modelling as a lens onto the real world; and understanding variation as the heart of statistics).

The focus on reasoning has implications for the background questionnaires which should provide measures to understand students' opportunities to learn to reason mathematically and employ the key understandings that undergird school mathematics. In particular the questionnaires should establish the frequency with which students, for example:

- identify, recognise, organise, connect, and represent;
- construct, abstract, evaluate, deduce, justify, explain, and defend;
- interpret, make judgements, critique, refute, and qualify.

In addition to establishing the frequency of the opportunities (to learn) to reason, the questionnaires should get at what forms these opportunities take (verbal or written).

Finally, with respect to reasoning, the questionnaires should get a sense of the willingness of students to persist with tasks that involve reasoning.

In the case of teachers and teaching there is the need to better understand how they see the role of reasoning in mathematics in general and in their teaching and assessment practices in particular.

Computational thinking

Aspects of computational thinking form a rapidly evolving and growing dimension of both mathematics and mathematical literacy. The PISA 2022 mathematical literacy framework illustrates how computational thinking is both part of doing mathematics and impacting on doing mathematics. The *values and beliefs about learning* and *open-mindedness* modules of the background questionnaires can explore student's experience of the role of computational thinking in doing mathematics.

The PISA 2022 mathematical literacy framework draws attention to the different ways in which technology is both changing the world in which we live and changing what it means to engage in mathematics. Key questions for the background questionnaires include developing a deep understanding of first, how students' experiences of mathematics and doing mathematics are changing (if at all) and second, how classroom pedagogy is evolving due to the impact that technology is having on how students engages with mathematics and mathematical artifacts and on what it means to do mathematics. In the case of students, it is of interest to better understand how technology is impacting student performance which could be explored in the *task performance* module of the questionnaire framework. The pedagogical issues could be explored in both the *learning time and curriculum* and *teaching practices* modules.

The focus on computational thinking and the role of technology in both doing and teaching mathematics has implications for the background questionnaires which should provide measures to better understand students' opportunities to learn in this regard. In particular the questionnaires should establish the frequency with which students, for example:

- design or work with computer simulations and or computer models;
- code or program both inside the mathematics classroom and outside it;
- are exposed to Computer Mathematics Systems (CSM) (including dynamic geometry software; spreadsheets; programming software (e.g. Logo and Scratch); graphing calculators; games etc.).

Four focal content areas

In recognition of the changing world the PISA 2022 Mathematics Framework has suggested that four content areas within the existing content framework receive special focus. These content areas are: growth phenomena (within change and relationships); geometric approximation (within space and shape); computer simulations (within quantity); and conditional decision making (within uncertainty and data). The focus on these content areas has implications for the background questionnaires which should provide measures to better understand students' opportunities to learn in this regard. In particular the questionnaires should establish the frequency with which students are exposed to these contents and the different forms that the opportunities take.

21st Century skills in the context of mathematics

The PISA 2022 mathematical literacy framework introduces a particular set of 21st Century skills both as an outcome of and focus for mathematics. The background questionnaires could productively examine both whether or not mathematics is contributing to the development of these skills and if teaching practices are focusing on them. In particular, the *learning time and curriculum* module could explore whether or not these skills appear in the enacted curriculum.

The results of the PISA 2022 survey will provide important information for educational policy makers in the participating countries about both the achievement-related and attitude-related outcomes of schooling. By combining information from the PISA assessment of mathematical literacy and the survey information on attitudes, emotions and beliefs that predispose students to use their mathematical literacy as well as the impact of the four developments described above, a more complete picture will emerge.

Conclusion

The PISA 2022 mathematical literacy framework while maintaining coherence with the previous mathematical literacy frameworks acknowledges that the world is ever changing and with it the demand for mathematically literate citizens to reason mathematically rather than reproducing mathematical techniques as routines,

The aim of PISA with regard to mathematical literacy is to develop indicators that show how effectively countries are preparing students to use mathematics in the everyday aspect of their personal, civic and professional lives, as constructive, engaged and reflective 21st Century citizens. To achieve this, PISA has developed a definition of mathematical literacy and an assessment framework that reflects the important components of this definition.

The mathematics assessment items selected for inclusion in PISA 2022, based on this definition and framework, are intended to reflect a balance between mathematical reasoning, problem solving processes, mathematical content and contexts.

The assessment design will assure valid measurement of ability across the range of achievement extending to two levels below the previous PISA scale, while preserving the quality and content of the assessment.

The CBAM to be used from 2022 provides problems in a variety of item formats with varying degrees of built-in guidance and structure and a range of formats retaining throughout an emphasis on authentic problems that require students to reason and demonstrate their thinking.

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Notes

[1] Throughout this framework, references to mathematical reasoning assume both mathematical (deductive) and statistical (inductive) type reasoning.

[2] The selected skills were recommended by the OECD Subject Advisory Group (SAG) (*PISA 2021 Mathematics: A Broadened Perspective* [EDU/PISA/GB(2017)17] by finding the union between generic 21st Century skills and related but subject-matter specific skills that are a natural part of the instruction related in the subject matter. The advisory group identified eight 21st Century skills for inclusion in the mathematics curriculum and, as such, in the PISA 2022 assessment framework. These skills are listed in paragraph 68.

[3] This activity is included in the list to foreground the need for the test items developers to include items that are accessible to students at the lower end of the performance scale.

[4] These activities (**) are included in the list to foreground the need for the test items developers to include items that are accessible to students at the lower end of the performance scale.

[5] These activities (**) are included in the list to foreground the need for the test items developers to include items that are accessible to students at the lower end of the performance scale.

Annex 2.A. Illustrative examples

The items included in this Annex illustrate some of the most important new elements of the framework. For the sake of ensuring the preservation of trend, the majority of the items in the PISA 2022 will be items that have been used in previous PISA assessments. A larger set of release items to illustrate the item pool can be found at http://www.oecd.org/pisa/test.

The items provided in this annex illustrate some of the following new elements:

- the assessment of mathematical reasoning as described in the framework;
- the four topics that have been identified for special emphasis in the PISA 2022 assessment, growth phenomena; geometric approximations; computer simulations; and conditional decision making;
- the range of item features that are possible on account of the Computer-Based Assessment of Mathematics (CBAM);
- computational thinking.

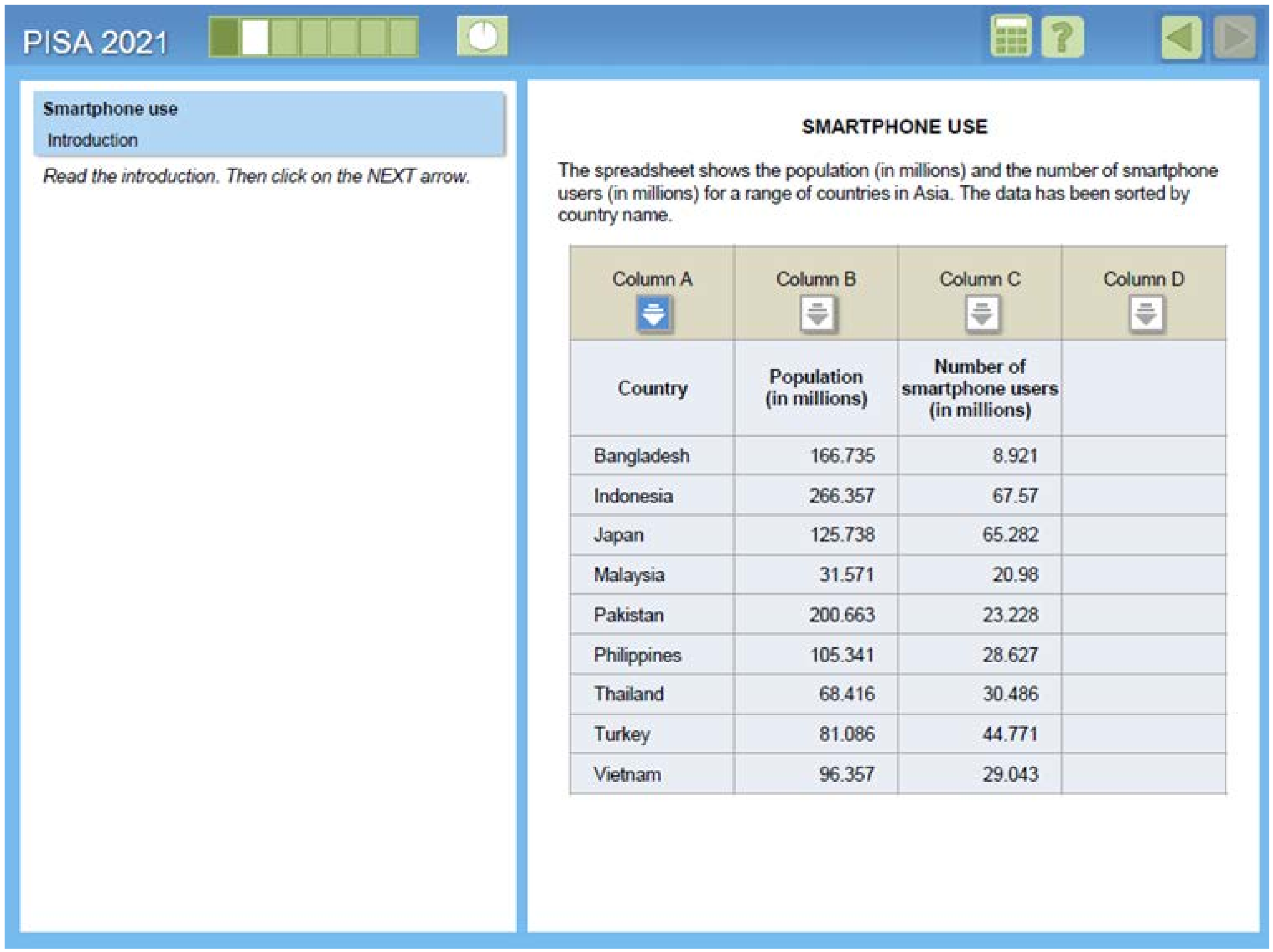
The seven illustrative items provided in this annex include:

- **Smartphone use**: This item illustrates:
  - CBAM capabilities in particular the use of spreadsheets with sorting and other capabilities.
- **The beauty of powers**: This item illustrates:
  - A range of mathematics reasoning items from simple to more complex in a mathematical context; and
  - Hints at growth phenomena, although, in fairness, the context for this item is more focused on reasoning and pattern recognition than it is on growth.
- **Always sometimes never**: This item illustrates:
  - A range of reasoning items from simple to more complex including a range of question types from yes/no and multiple choice to open-ended items
- **Tiling**: This item illustrates:
  - Reasoning and computational thinking; and

  - Geometric representations.
- **Purchasing decision**: This item illustrates:
  - The application of conditional decision making.
- **Navigation**: This item illustrates:
  - Reasoning in a geometric context; and
  - CBAM capabilities in items.
- **Savings simulation**: This item illustrates:
  - The use a computer simulation; and
  - Hints at growth in the context and impact of interest.

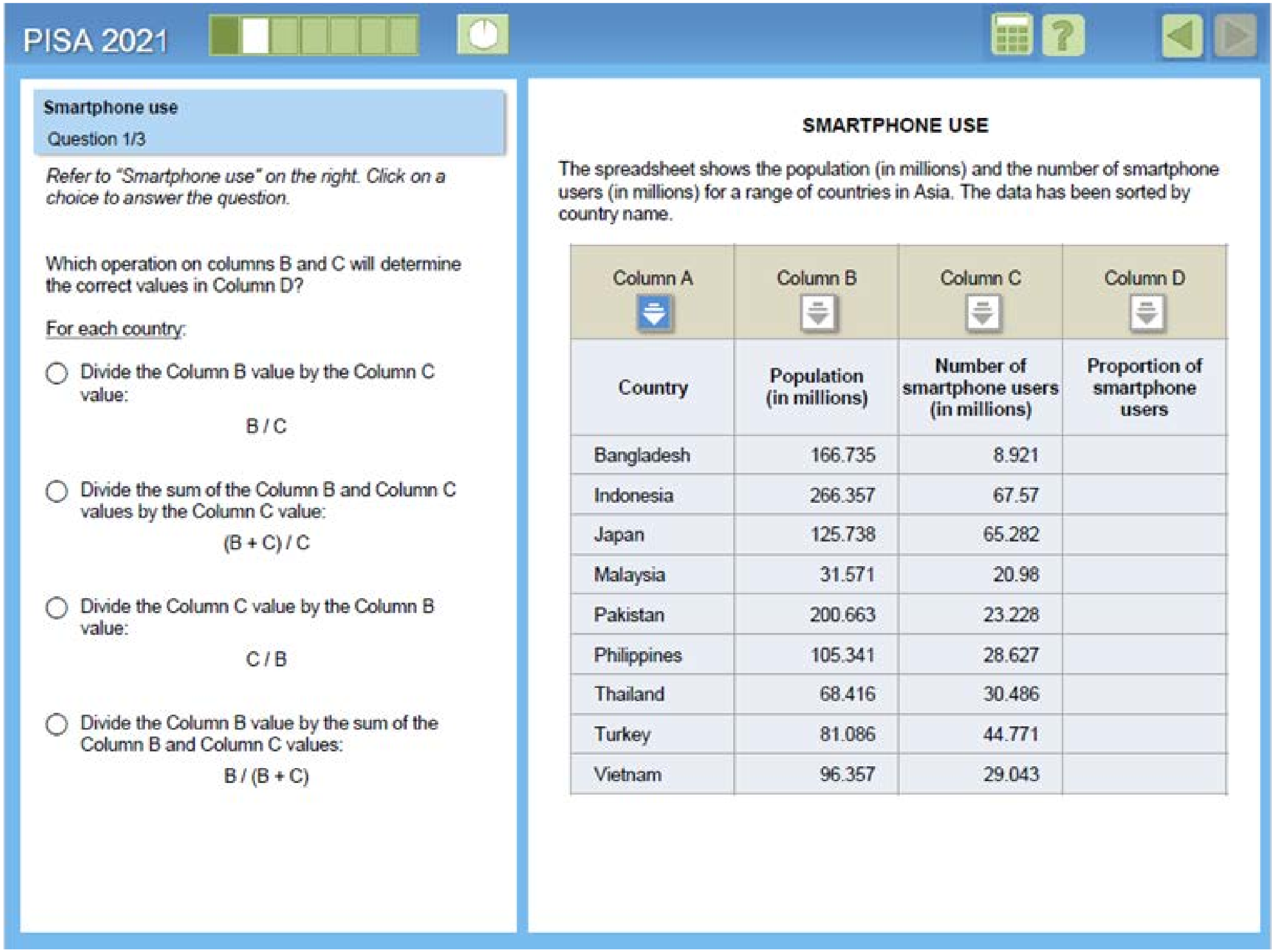
Smartphone use

Annex Figure 2.A.1. Smartphone use - Introduction



Column A	Column B	Column C	Column D
Country	Population (in millions)	Number of smartphone users (in millions)	
Bangladesh	166.735	8.921	
Indonesia	266.357	67.57	
Japan	125.738	65.282	
Malaysia	31.571	20.98	
Pakistan	200.663	23.228	
Philippines	105.341	28.627	
Thailand	68.416	30.486	
Turkey	81.086	44.771	
Vietnam	96.357	29.043	

Annex Figure 2.A.2. Smartphone use - Question 1/3



PISA 2021

Smartphone use

Question 1/3

Refer to "Smartphone use" on the right. Click on a choice to answer the question.

Which operation on columns B and C will determine the correct values in Column D?

For each country:

- ○ Divide the Column B value by the Column C value:

  B / C

- ○ Divide the sum of the Column B and Column C values by the Column C value:

  (B + C) / C

- ○ Divide the Column C value by the Column B value:

  C / B

- ○ Divide the Column B value by the sum of the Column B and Column C values:

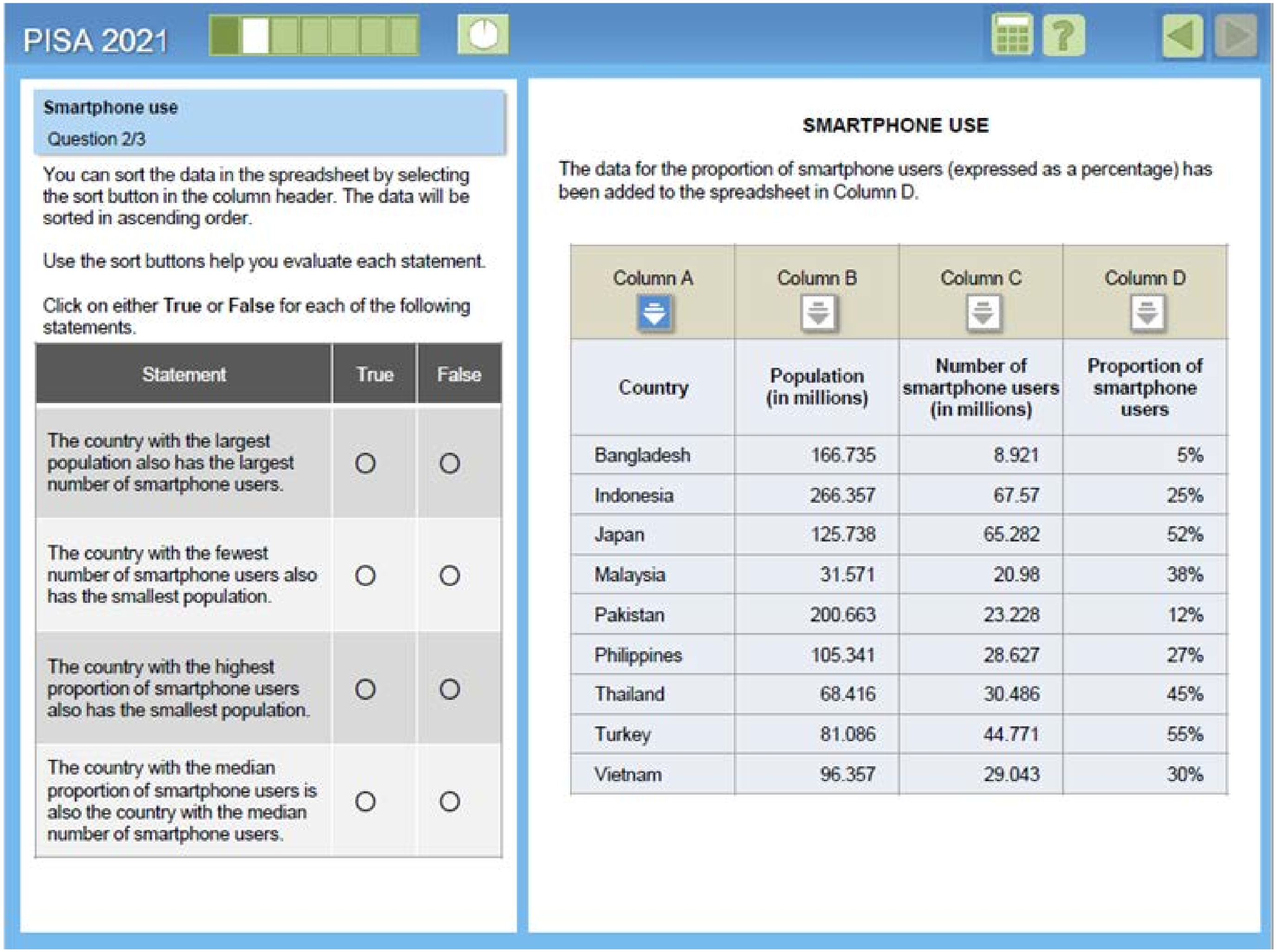
  B / (B + C)

SMARTPHONE USE

The spreadsheet shows the population (in millions) and the number of smartphone users (in millions) for a range of countries in Asia. The data has been sorted by country name.

Column A	Column B	Column C	Column D
Country	**Population (in millions)**	**Number of smartphone users (in millions)**	**Proportion of smartphone users**
Bangladesh	166.735	8.921	
Indonesia	266.357	67.57	
Japan	125.738	65.282	
Malaysia	31.571	20.98	
Pakistan	200.663	23.228	
Philippines	105.341	28.627	
Thailand	68.416	30.486	
Turkey	81.086	44.771	
Vietnam	96.357	29.043	

Annex Figure 2.A.3. Smartphone use - Question 2/3


PISA 2021

Smartphone use
Question 2/3

You can sort the data in the spreadsheet by selecting the sort button in the column header. The data will be sorted in ascending order.

Use the sort buttons help you evaluate each statement.

Click on either **True** or **False** for each of the following statements.

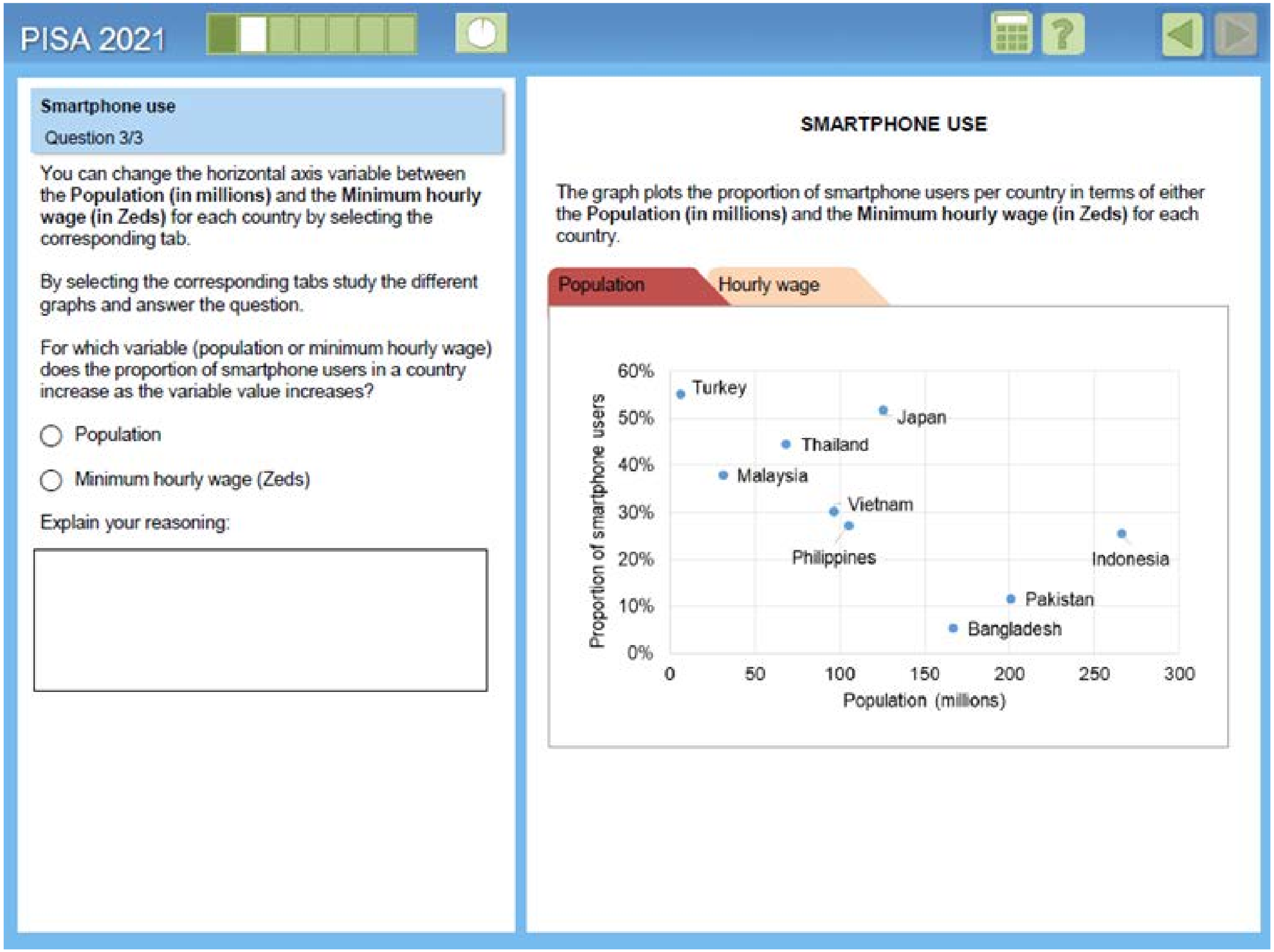
Statement	True	False
The country with the largest population also has the largest number of smartphone users.	○	○
The country with the fewest number of smartphone users also has the smallest population.	○	○
The country with the highest proportion of smartphone users also has the smallest population.	○	○
The country with the median proportion of smartphone users is also the country with the median number of smartphone users.	○	○

SMARTPHONE USE

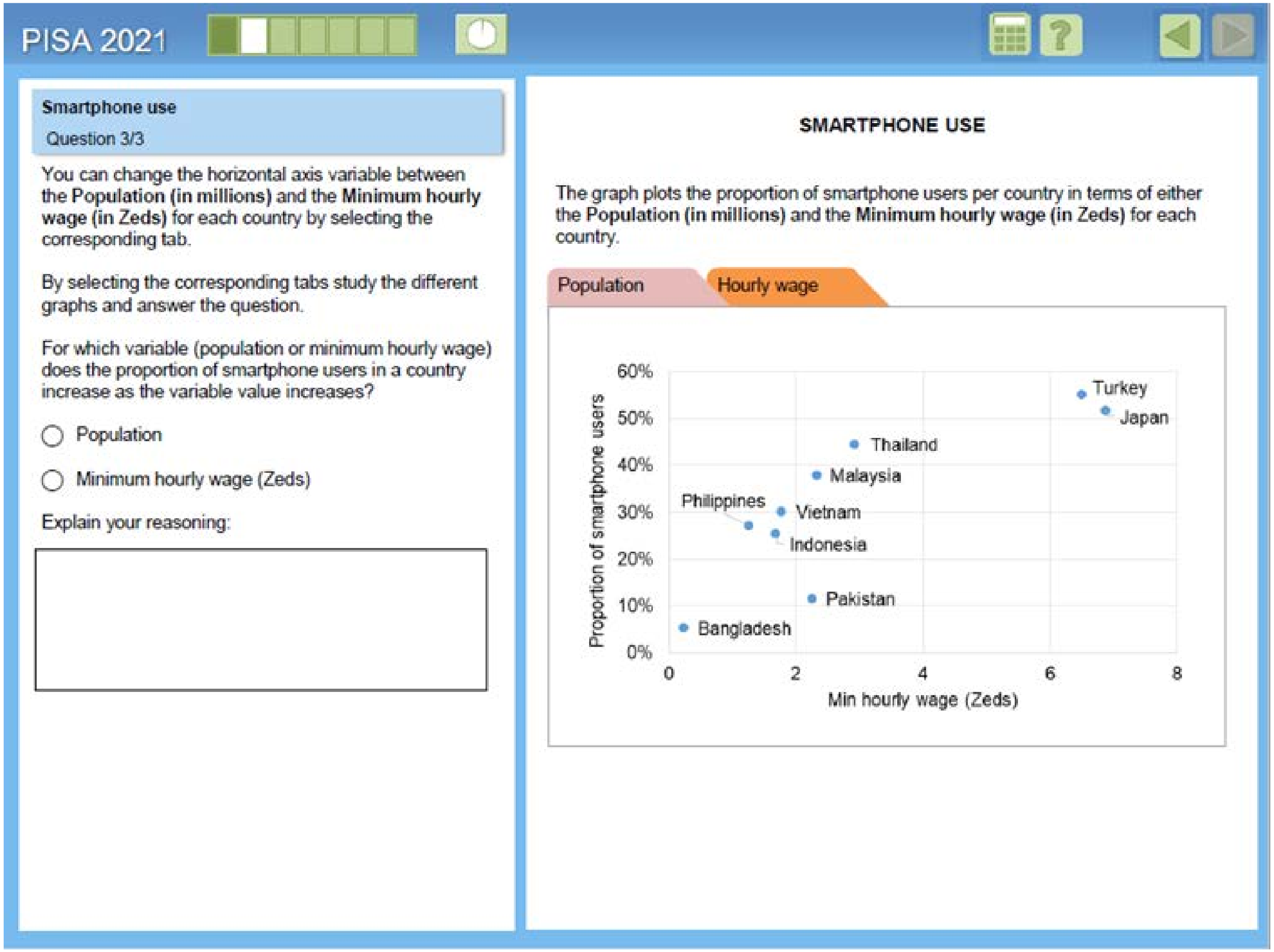
The data for the proportion of smartphone users (expressed as a percentage) has been added to the spreadsheet in Column D.

Column A	Column B	Column C	Column D
Country	**Population (in millions)**	**Number of smartphone users (in millions)**	**Proportion of smartphone users**
Bangladesh	166.735	8.921	5%
Indonesia	266.357	67.57	25%
Japan	125.738	65.282	52%
Malaysia	31.571	20.98	38%
Pakistan	200.663	23.228	12%
Philippines	105.341	28.627	27%
Thailand	68.416	30.486	45%
Turkey	81.086	44.771	55%
Vietnam	96.357	29.043	30%

Annex Figure 2.A.4. Smartphone use - Question 3/3 Population

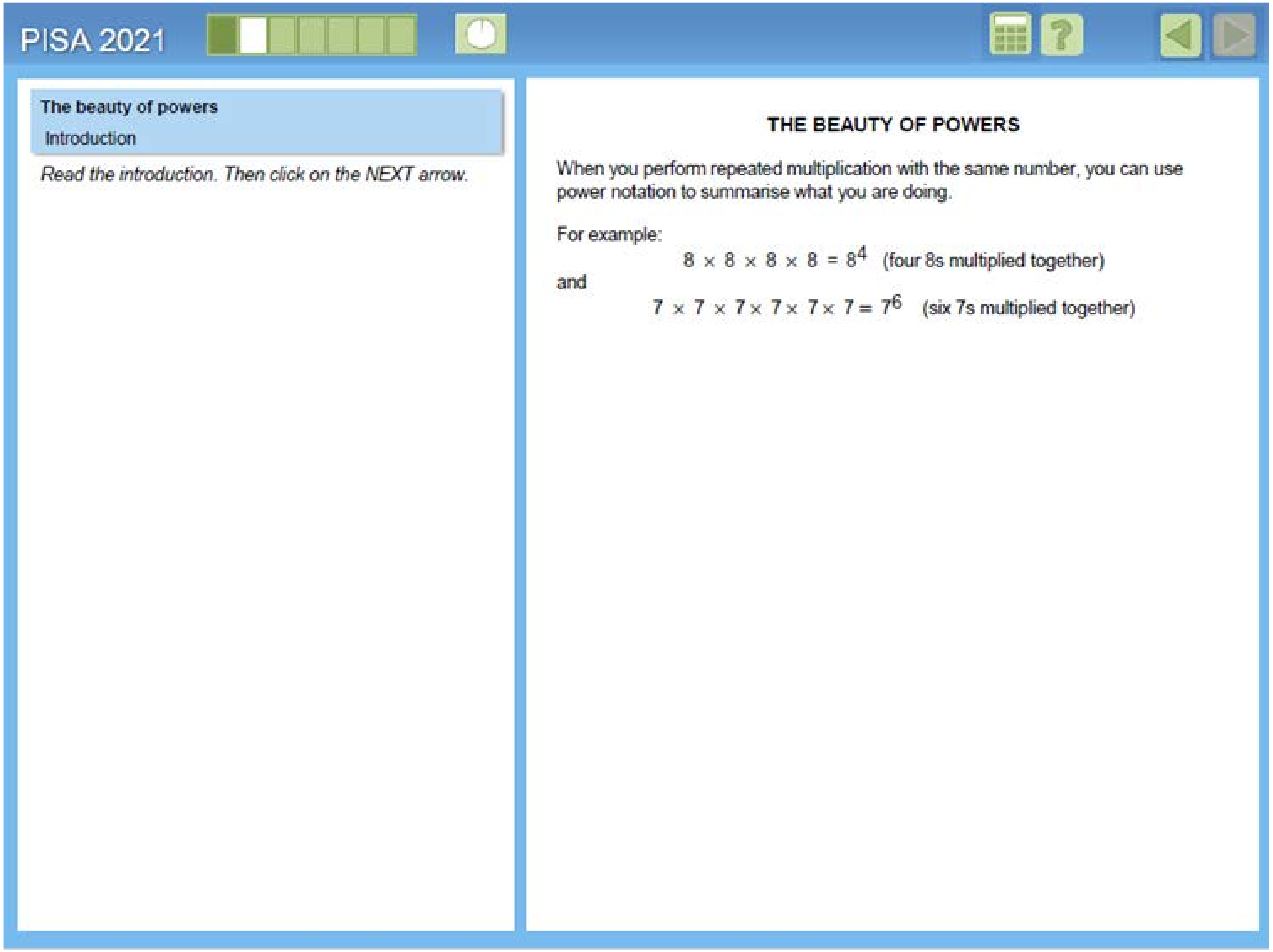


Annex Figure 2.A.5. Smartphone use - Question 3/3 Hourly wage

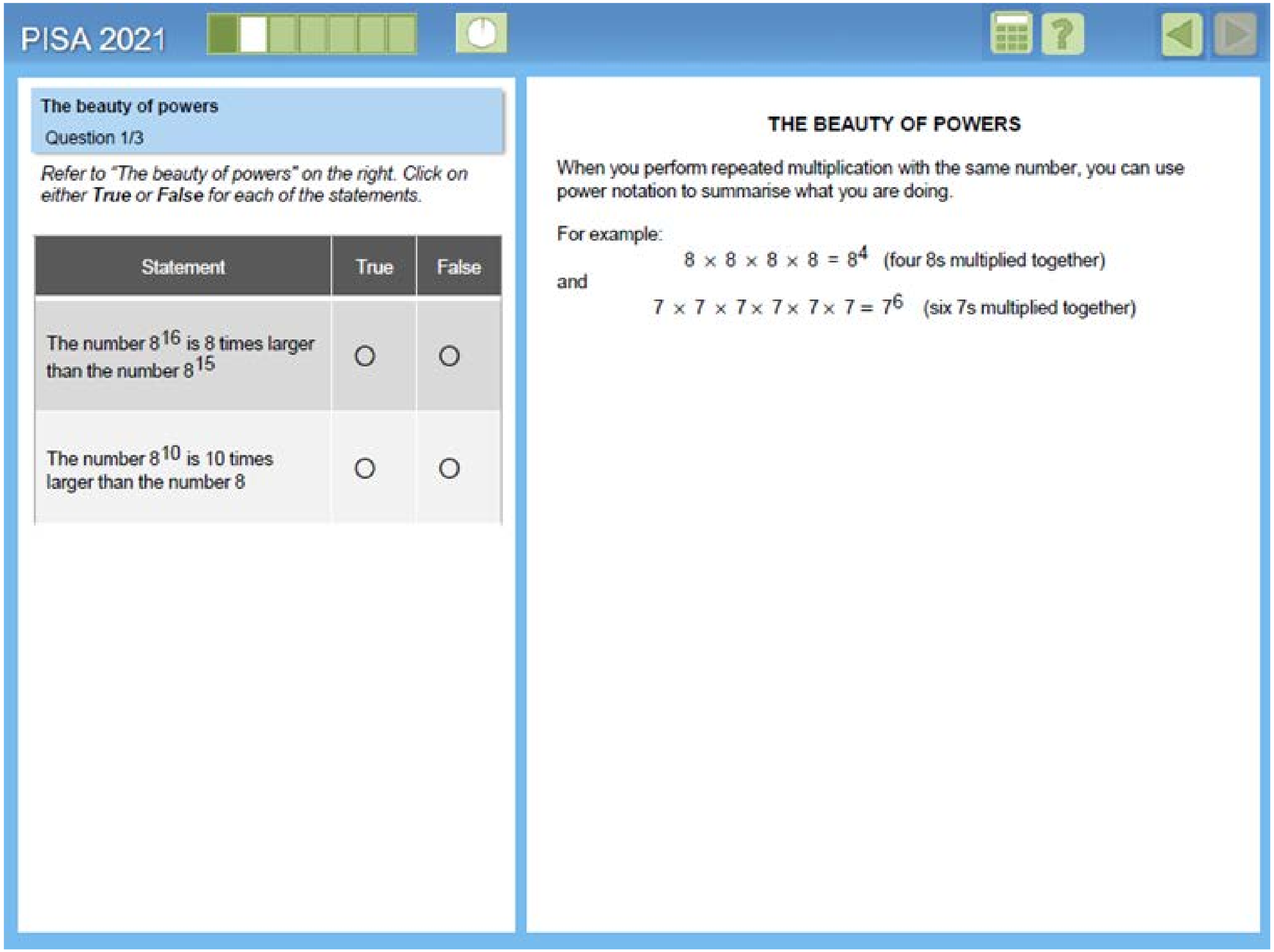


The beauty of powers

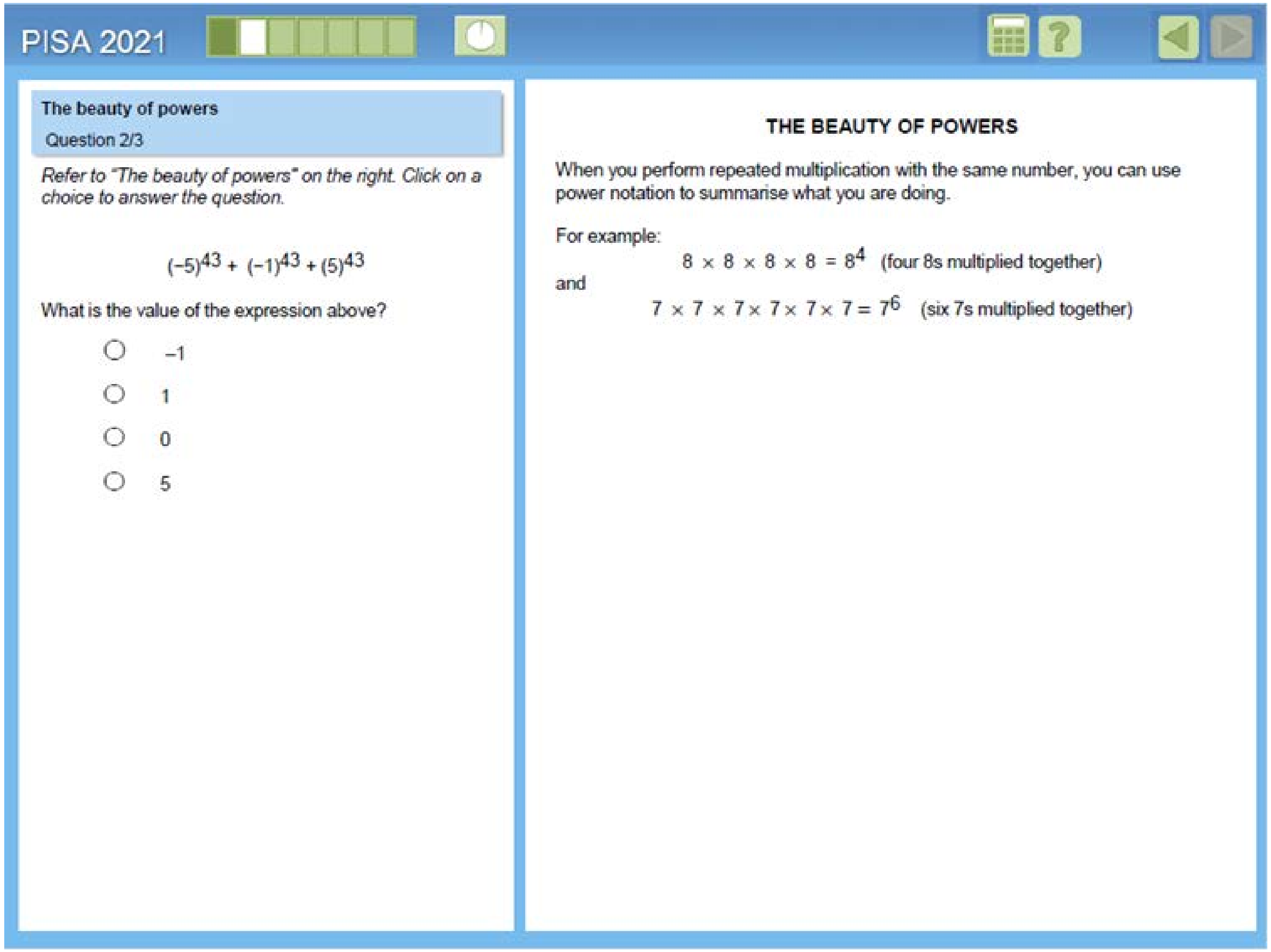
Annex Figure 2.A.6. The beauty of powers - Introduction



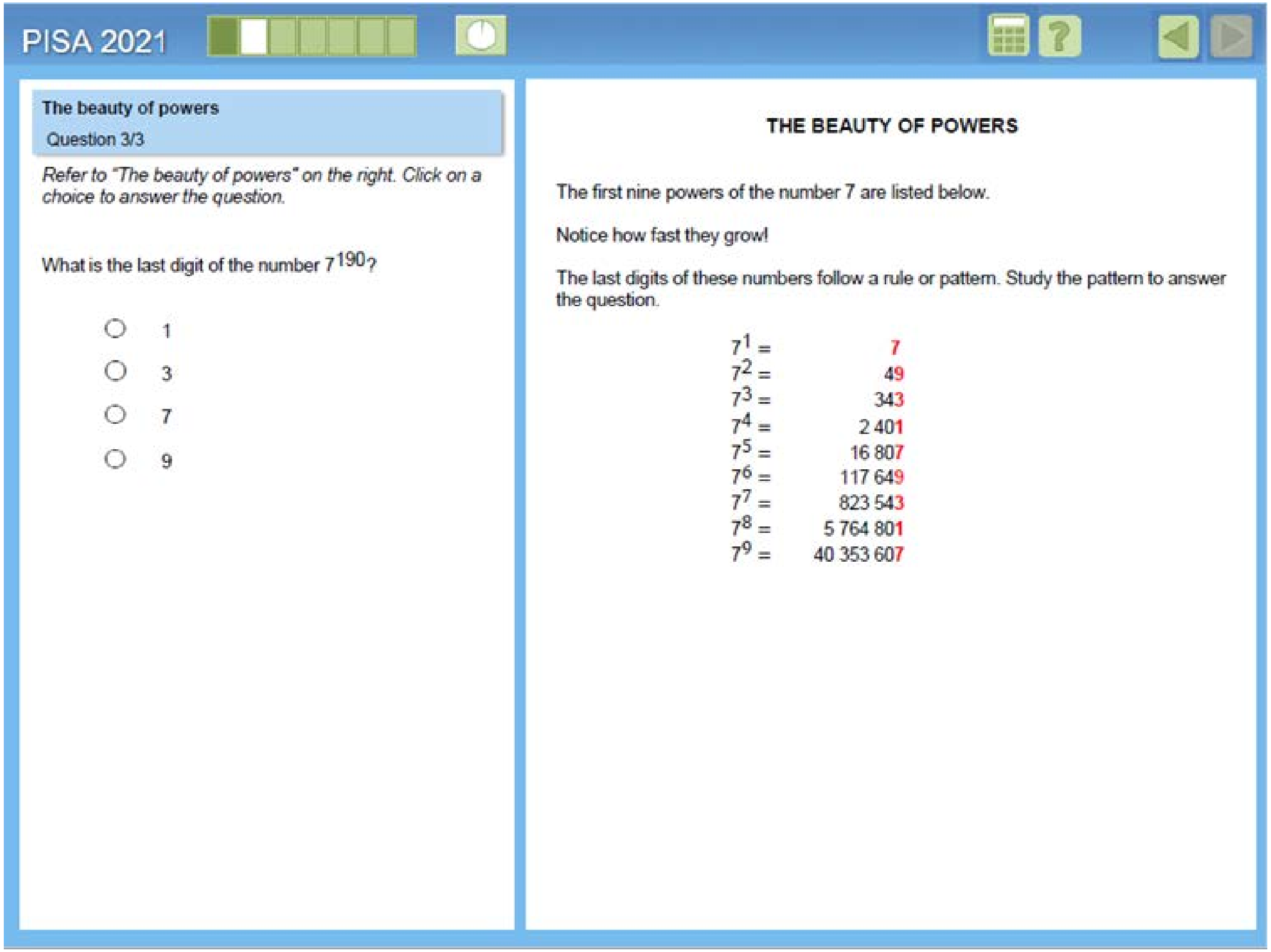
Annex Figure 2.A.7. The beauty of powers - Question 1/3



Annex Figure 2.A.8. The beauty of powers - Question 2/3

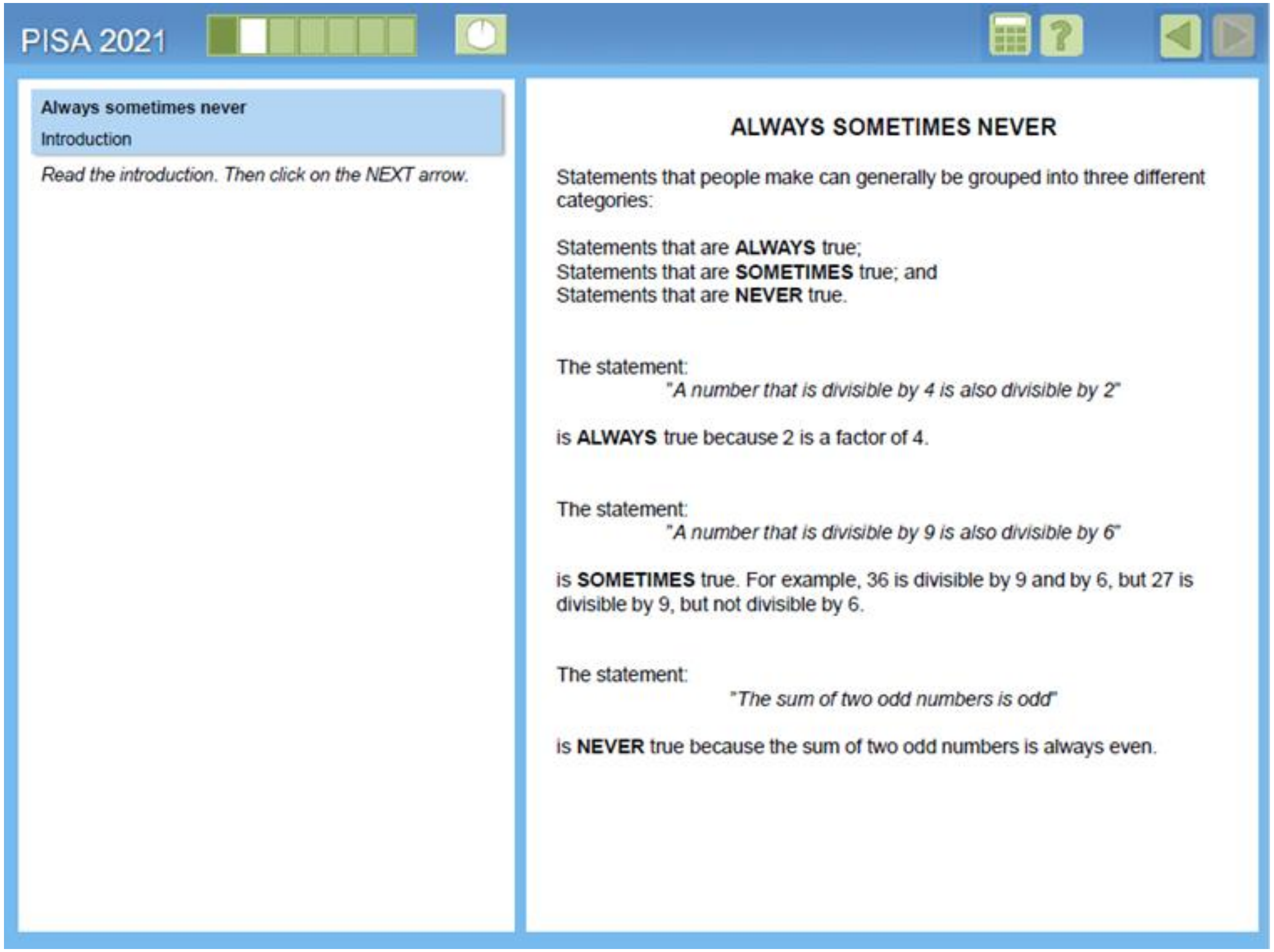


Annex Figure 2.A.9. The beauty of powers - Question 3/3

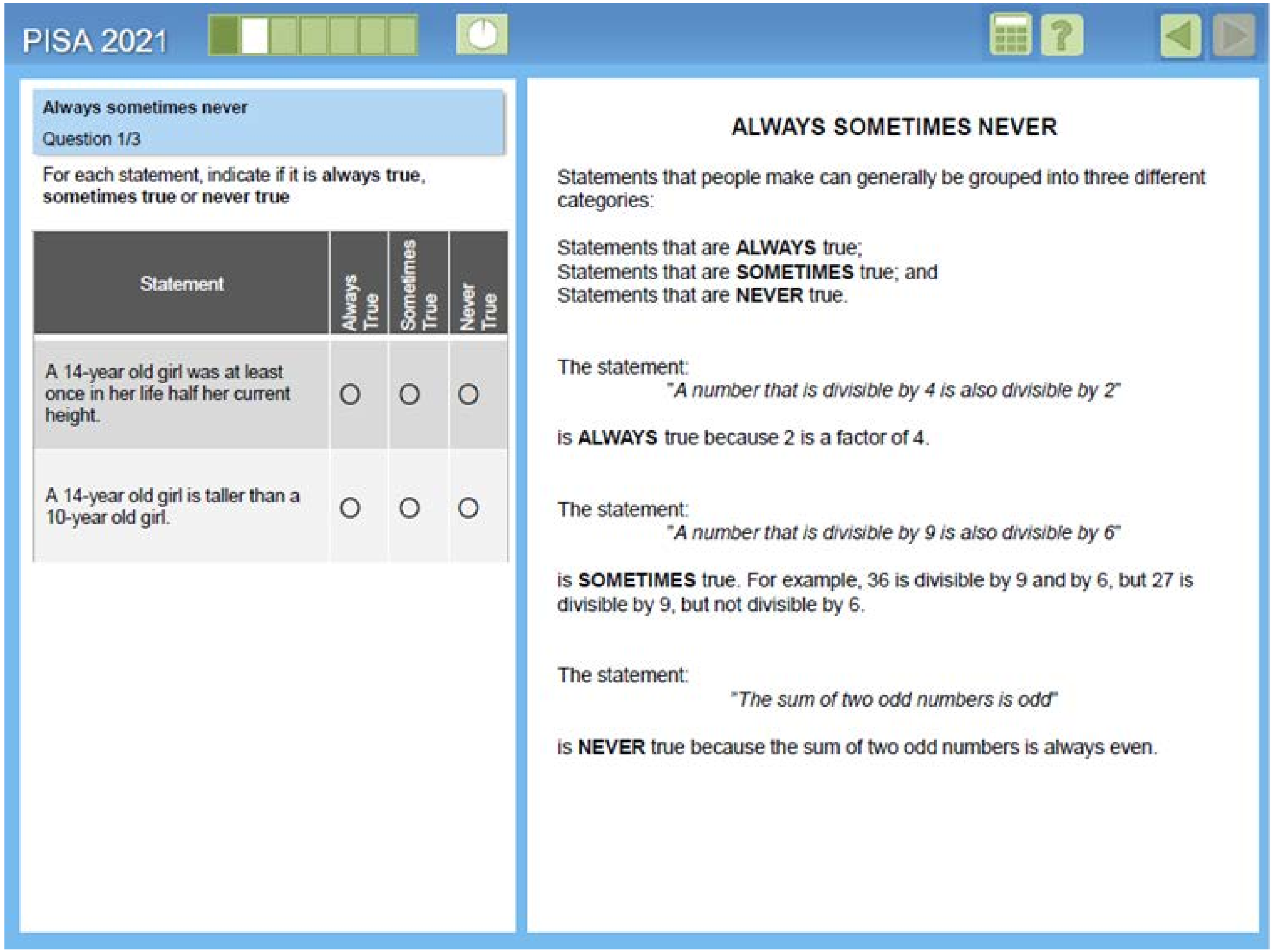


Always sometimes never

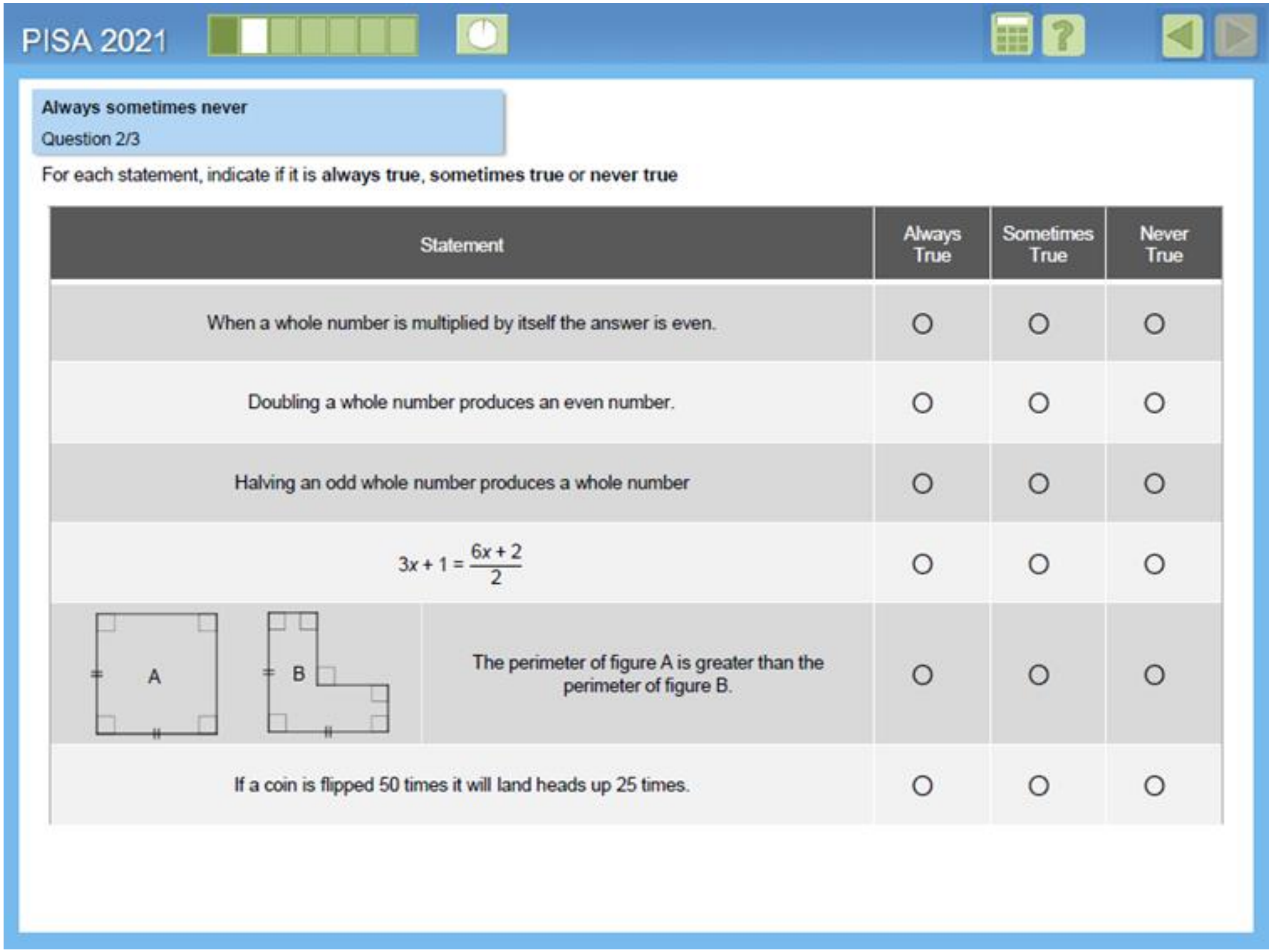
Annex Figure 2.A.10. Always sometimes never - Introduction



Annex Figure 2.A.11. Always sometimes never - Question 1/3



Annex Figure 2.A.12. Always sometimes never - Question 2/3



PISA 2021

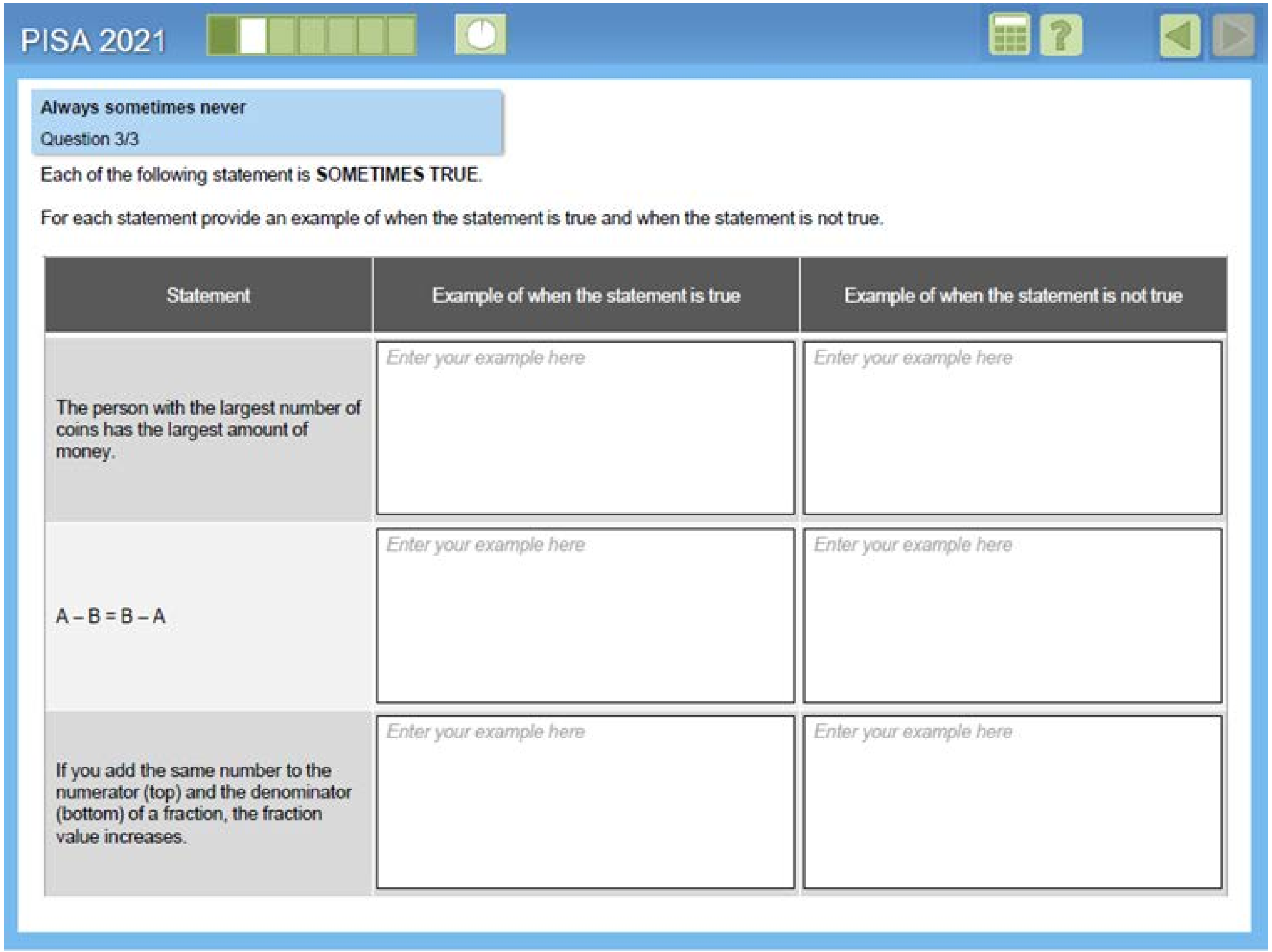
Always sometimes never

Question 2/3

For each statement, indicate if it is **always true**, **sometimes true** or **never true**

Statement	Always True	Sometimes True	Never True
When a whole number is multiplied by itself the answer is even.	○	○	○
Doubling a whole number produces an even number.	○	○	○
Halving an odd whole number produces a whole number	○	○	○
$3x + 1 = \frac{6x + 2}{2}$	○	○	○
A B The perimeter of figure A is greater than the perimeter of figure B.	○	○	○
If a coin is flipped 50 times it will land heads up 25 times.	○	○	○

Annex Figure 2.A.13. Always sometimes never - Question 3/3



PISA 2021

Always sometimes never

Question 3/3

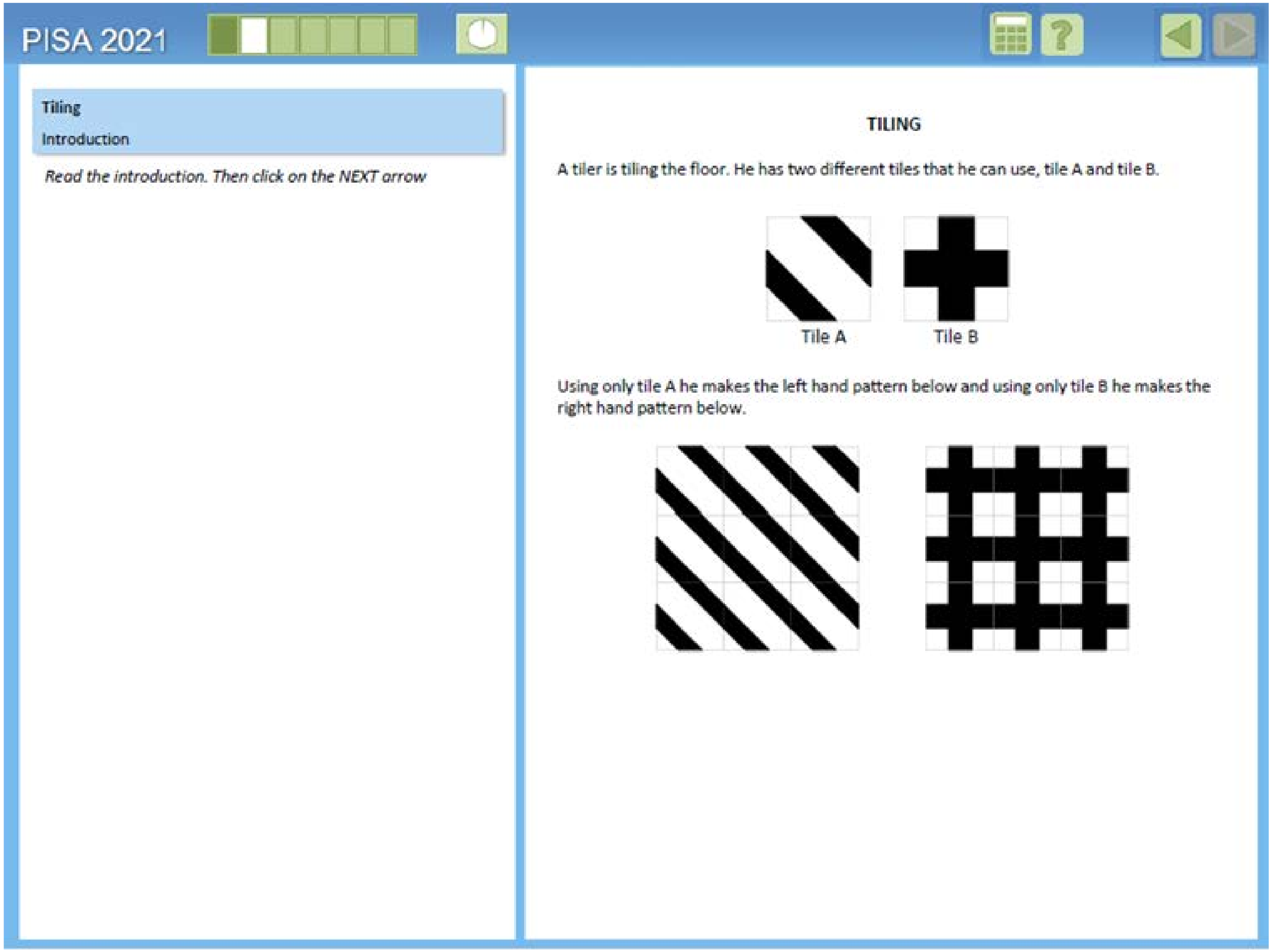
Each of the following statement is **SOMETIMES TRUE**.

For each statement provide an example of when the statement is true and when the statement is not true.

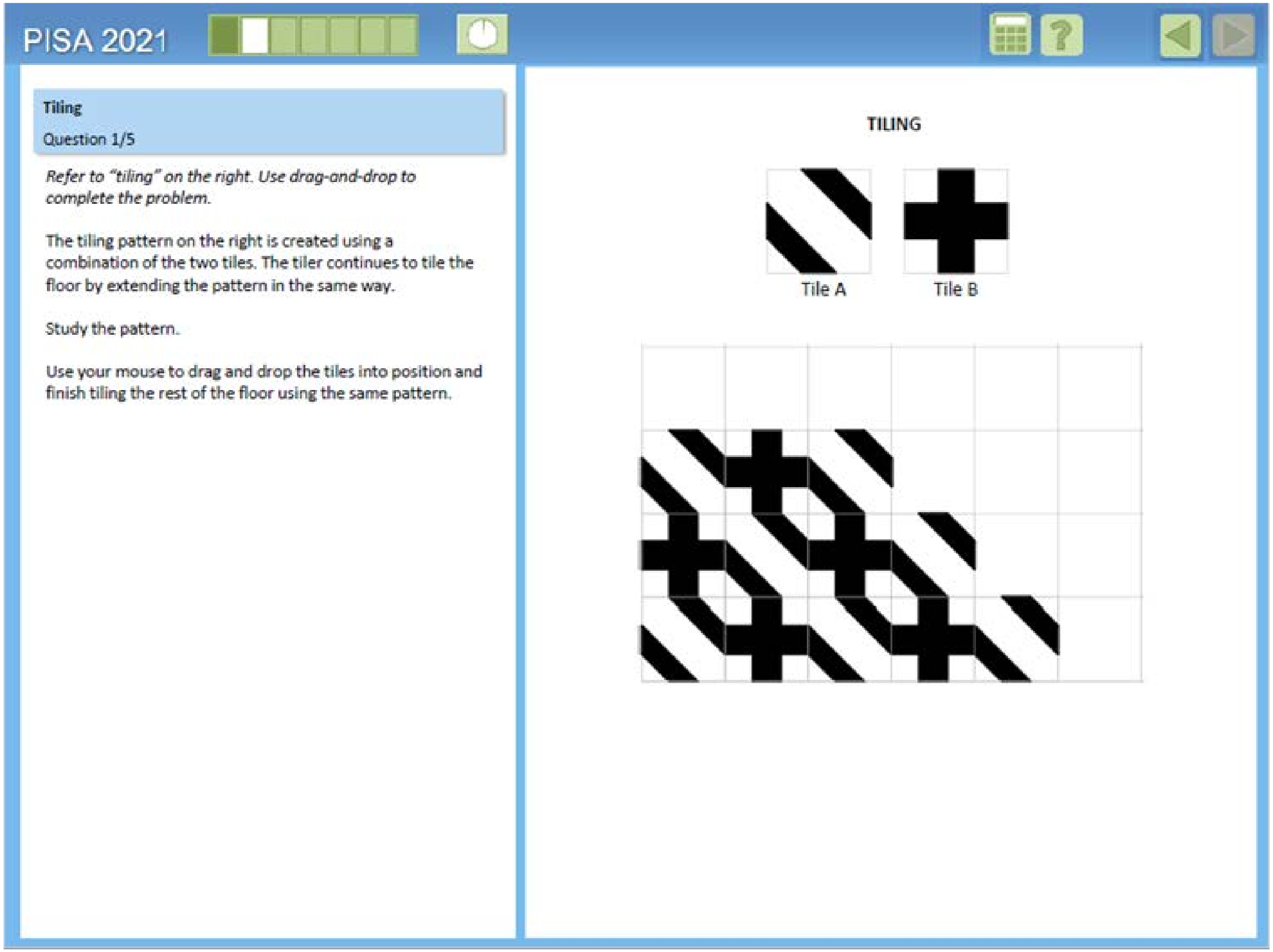
Statement	Example of when the statement is true	Example of when the statement is not true
The person with the largest number of coins has the largest amount of money.	*Enter your example here*	*Enter your example here*
A – B = B – A	*Enter your example here*	*Enter your example here*
If you add the same number to the numerator (top) and the denominator (bottom) of a fraction, the fraction value increases.	*Enter your example here*	*Enter your example here*

Tiling

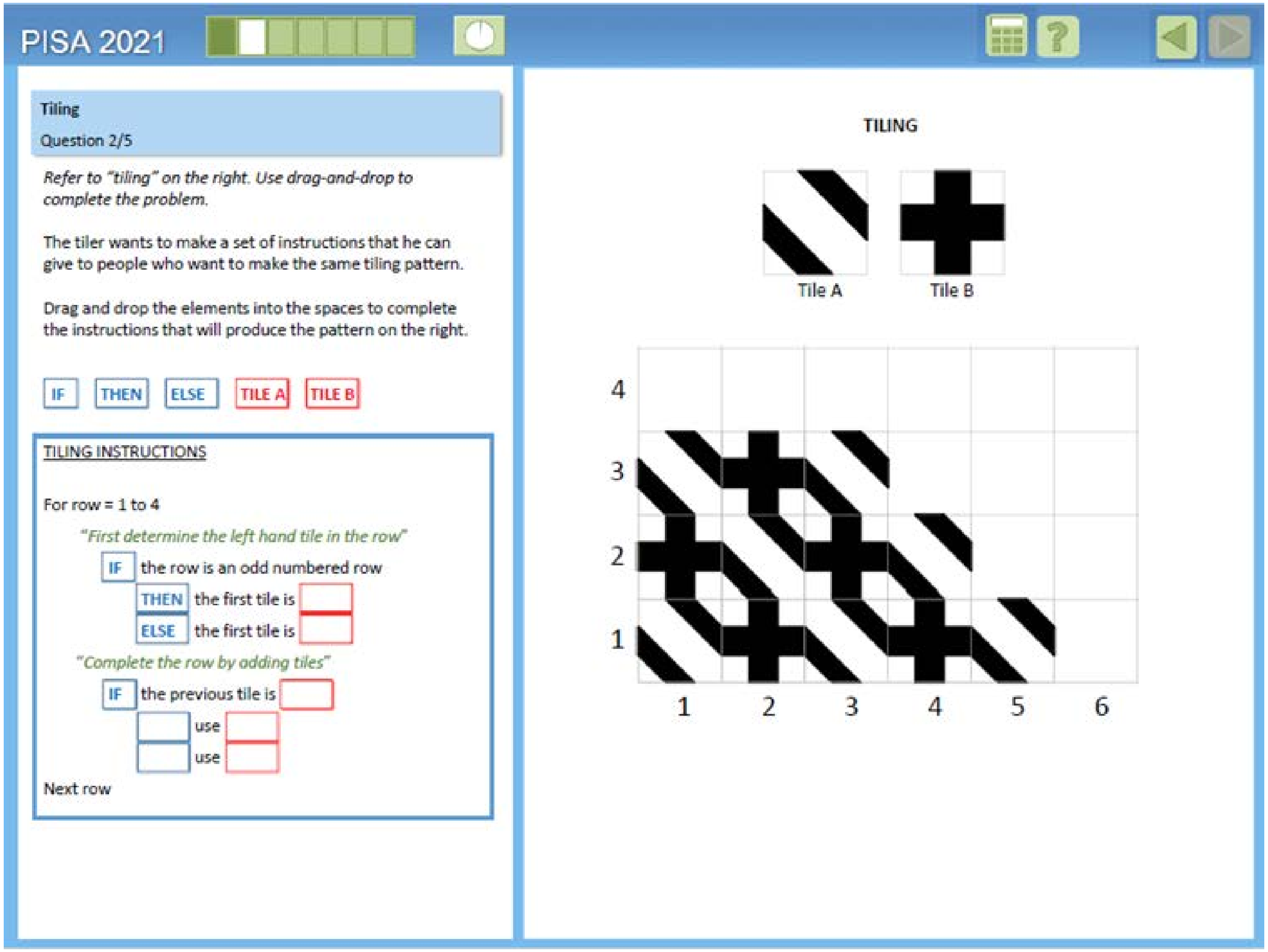
Annex Figure 2.A.14. Tiling - Introduction



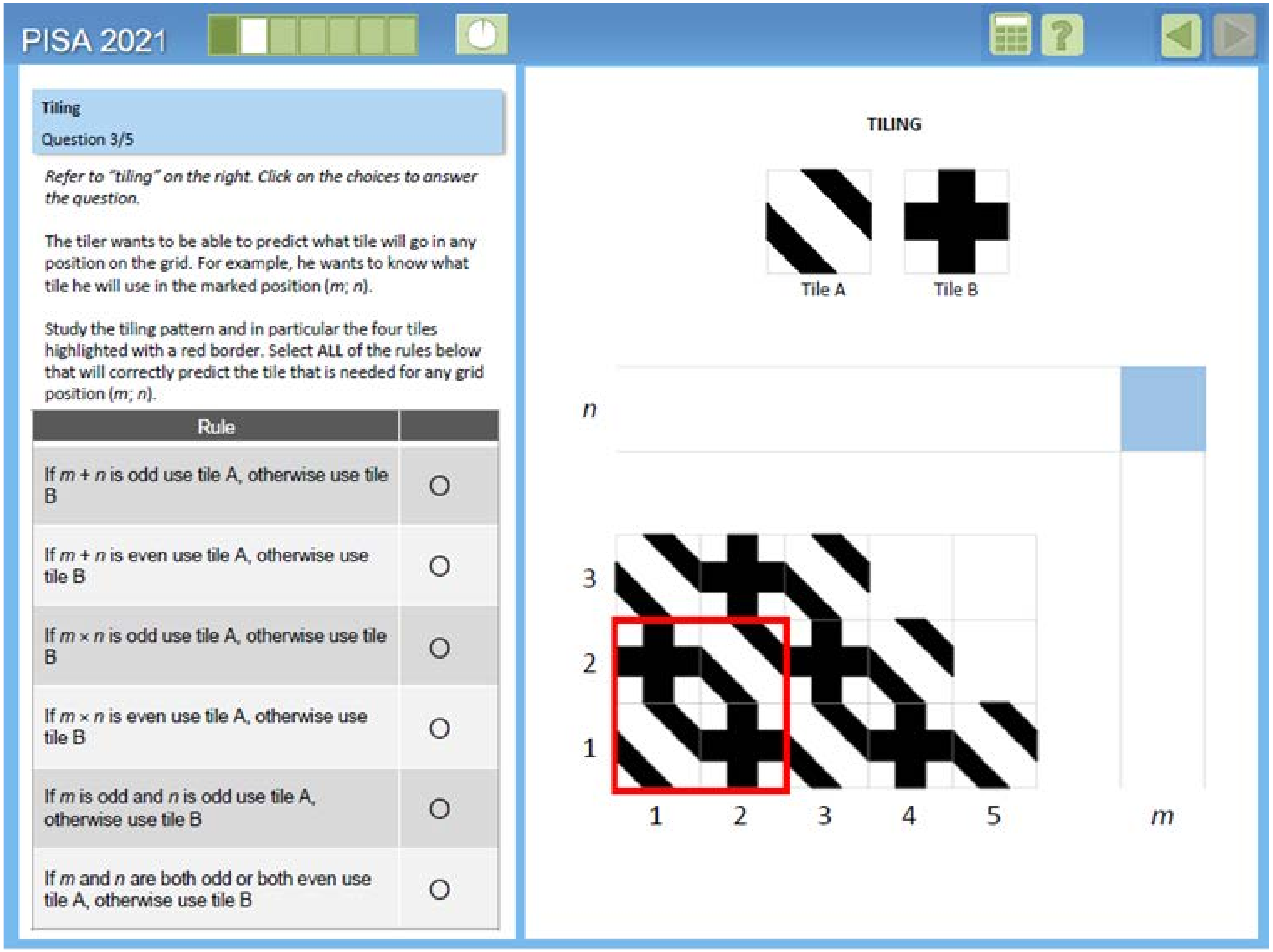
Annex Figure 2.A.15. Tiling – Question 1/5



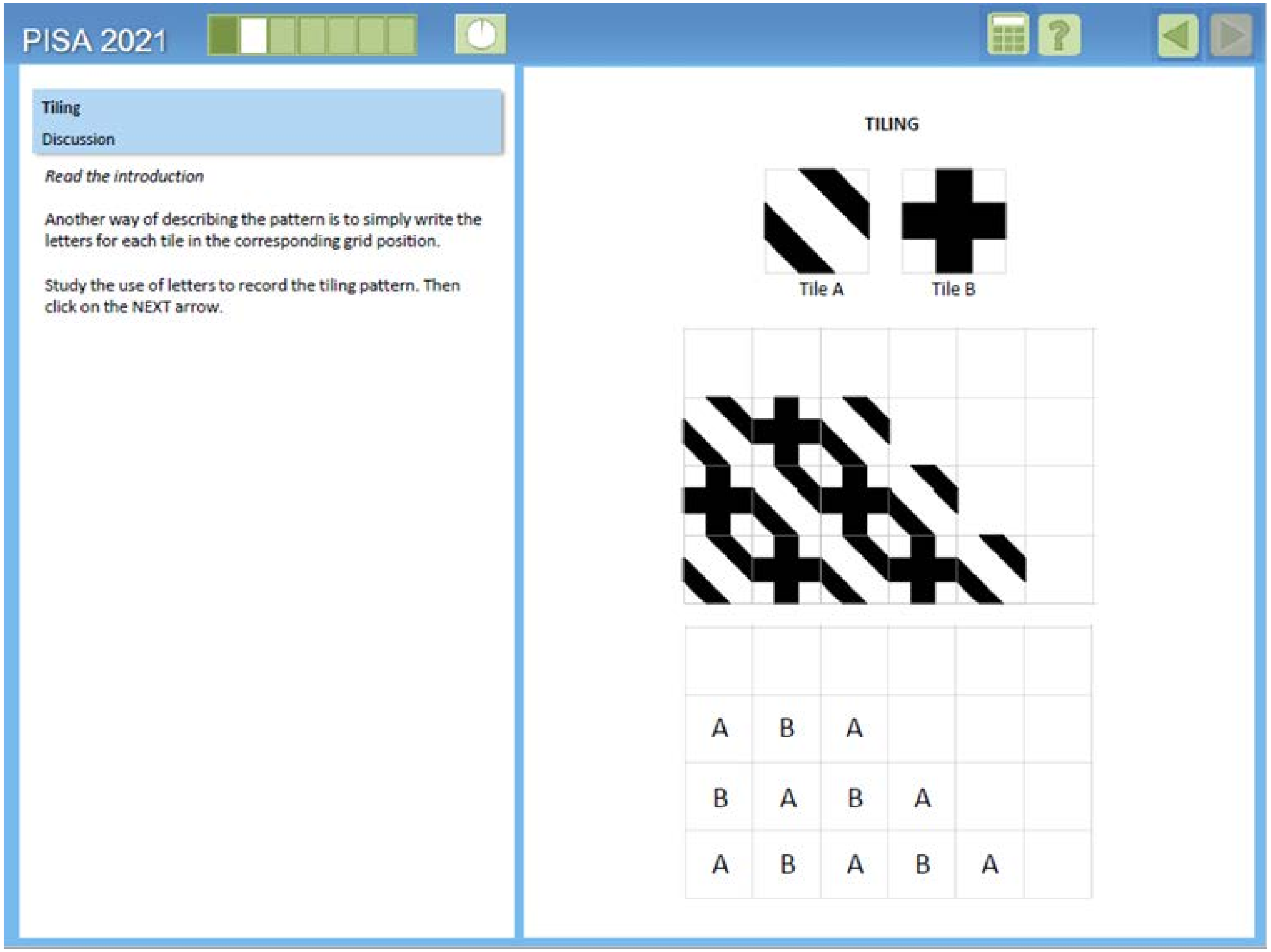
Annex Figure 2.A.16. Tiling – Question 2/5



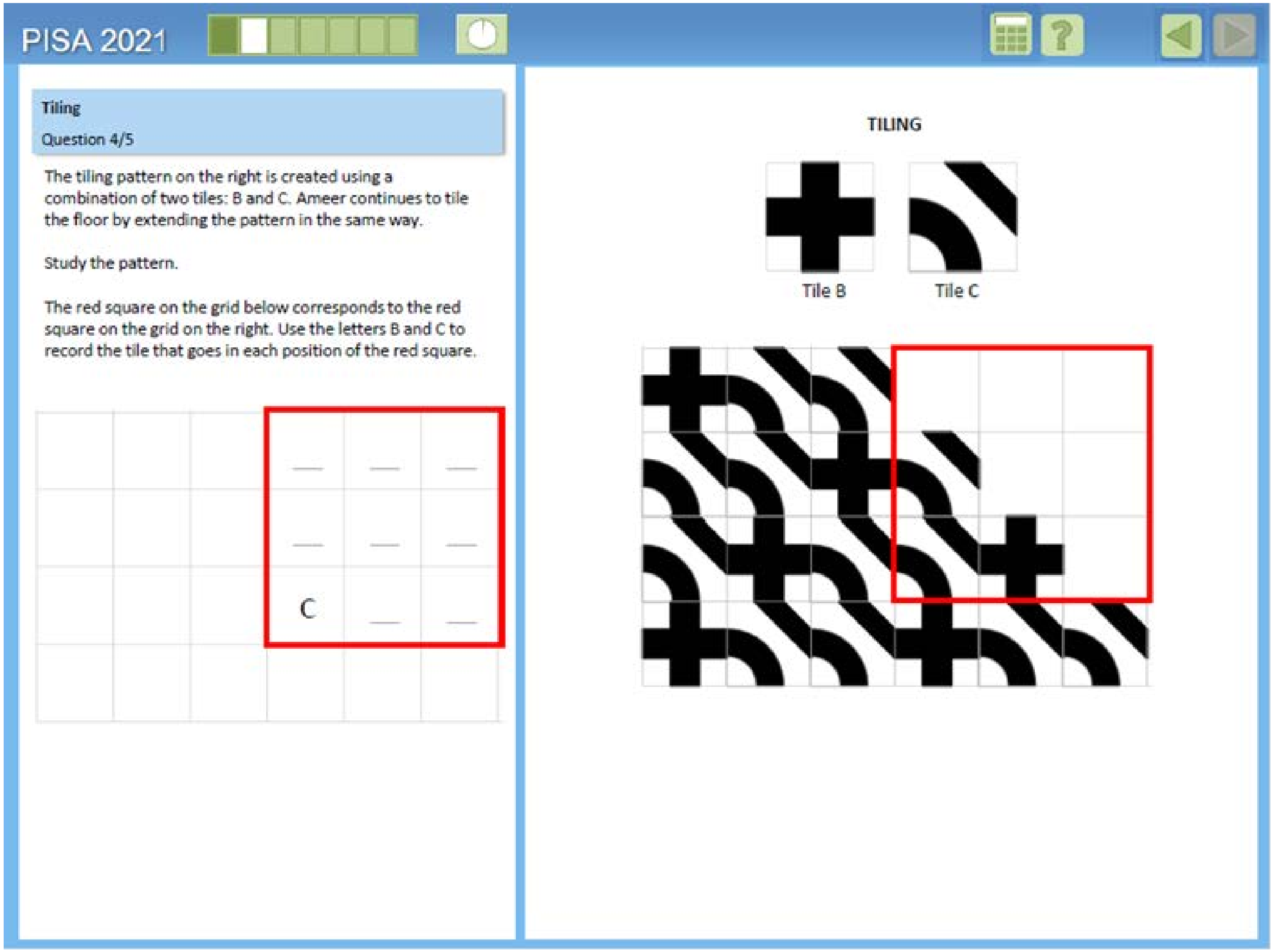
Annex Figure 2.A.17. Tiling – Question 3/5



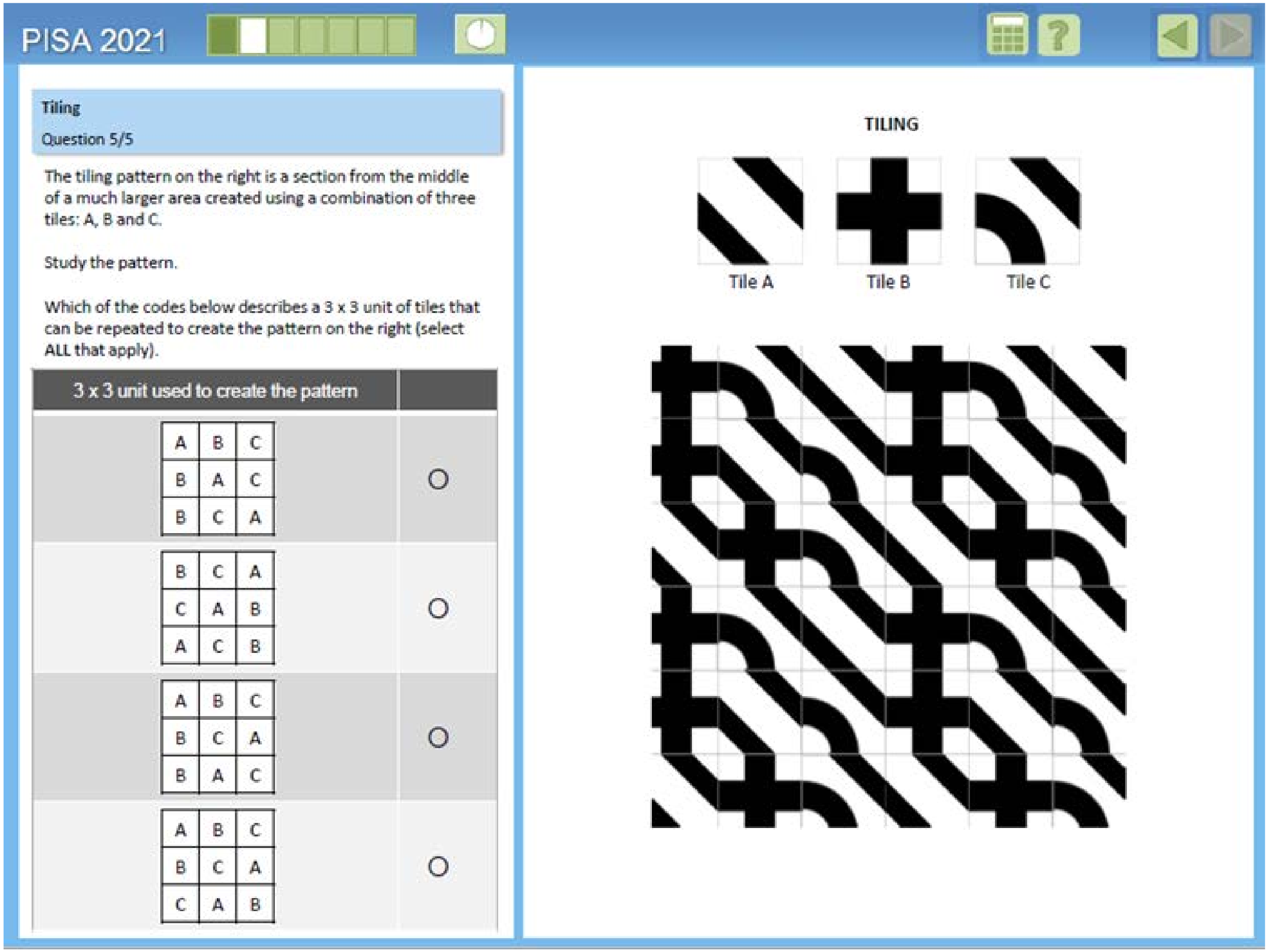
Annex Figure 2.A.18. Tiling - Discussion



Annex Figure 2.A.19. Tiling – Question 4/5

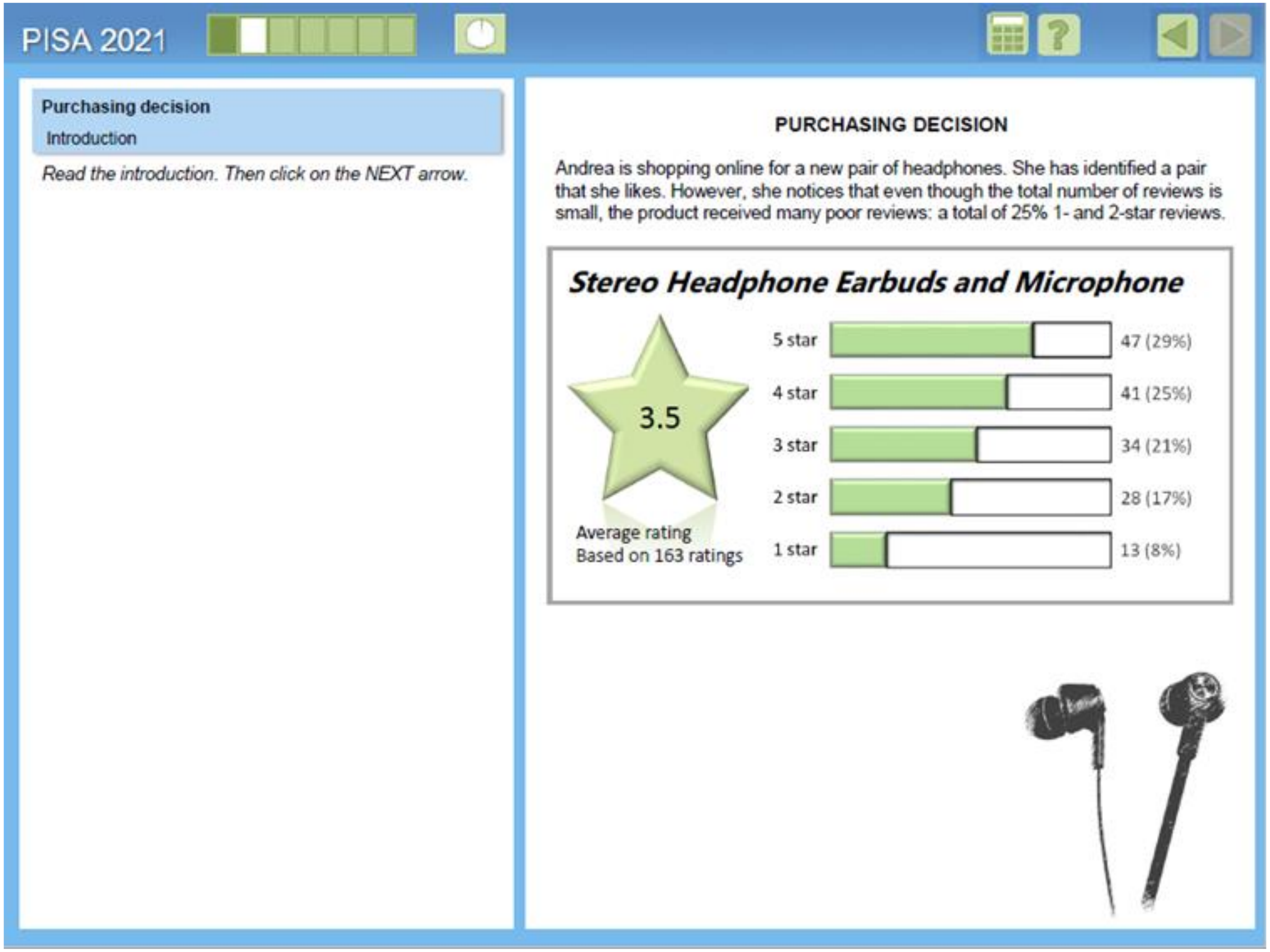


Annex Figure 2.A.20. Tiling – Question 5/5

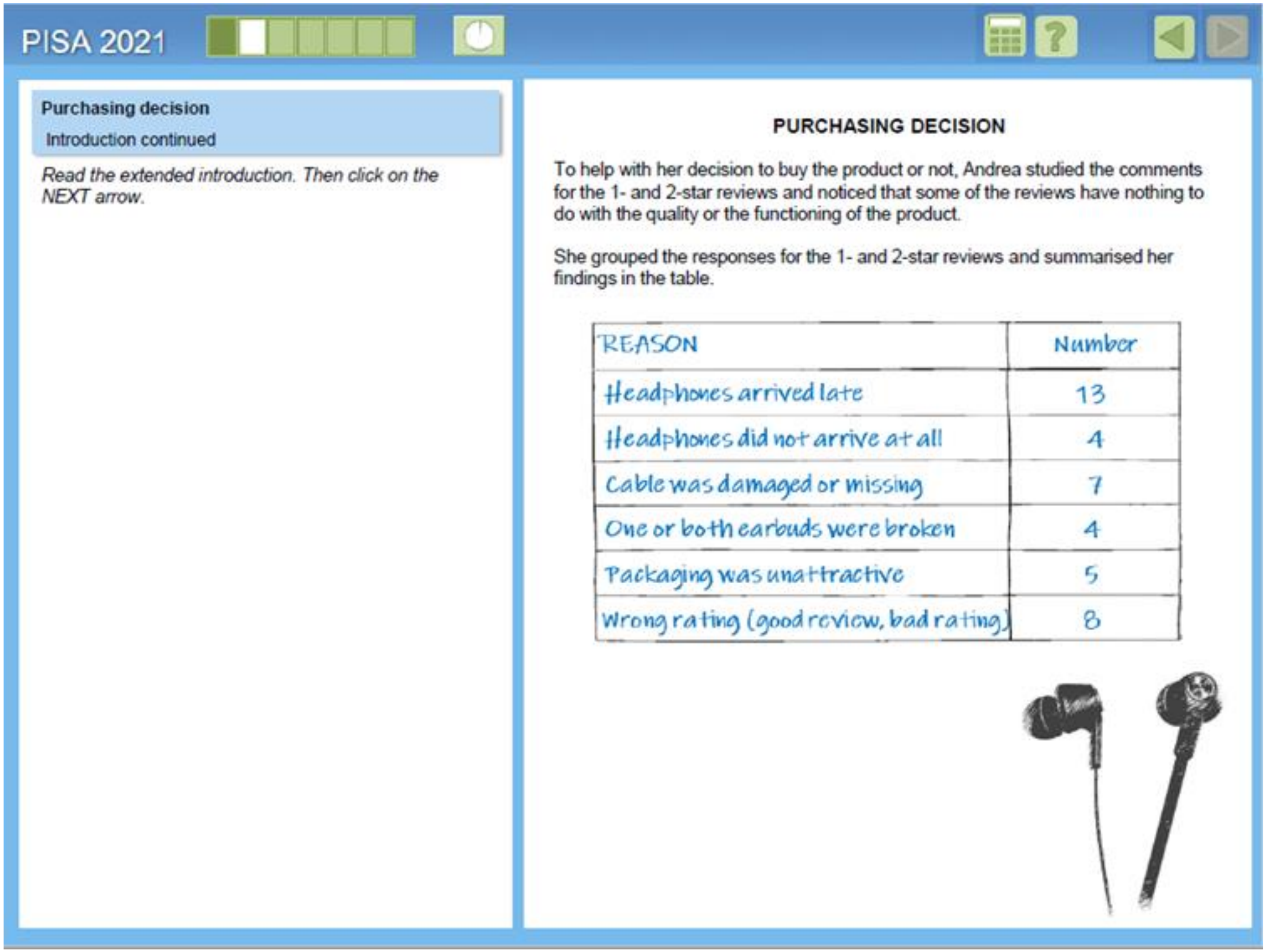


Purchasing decision

Annex Figure 2.A.21. Purchasing decision - Introduction

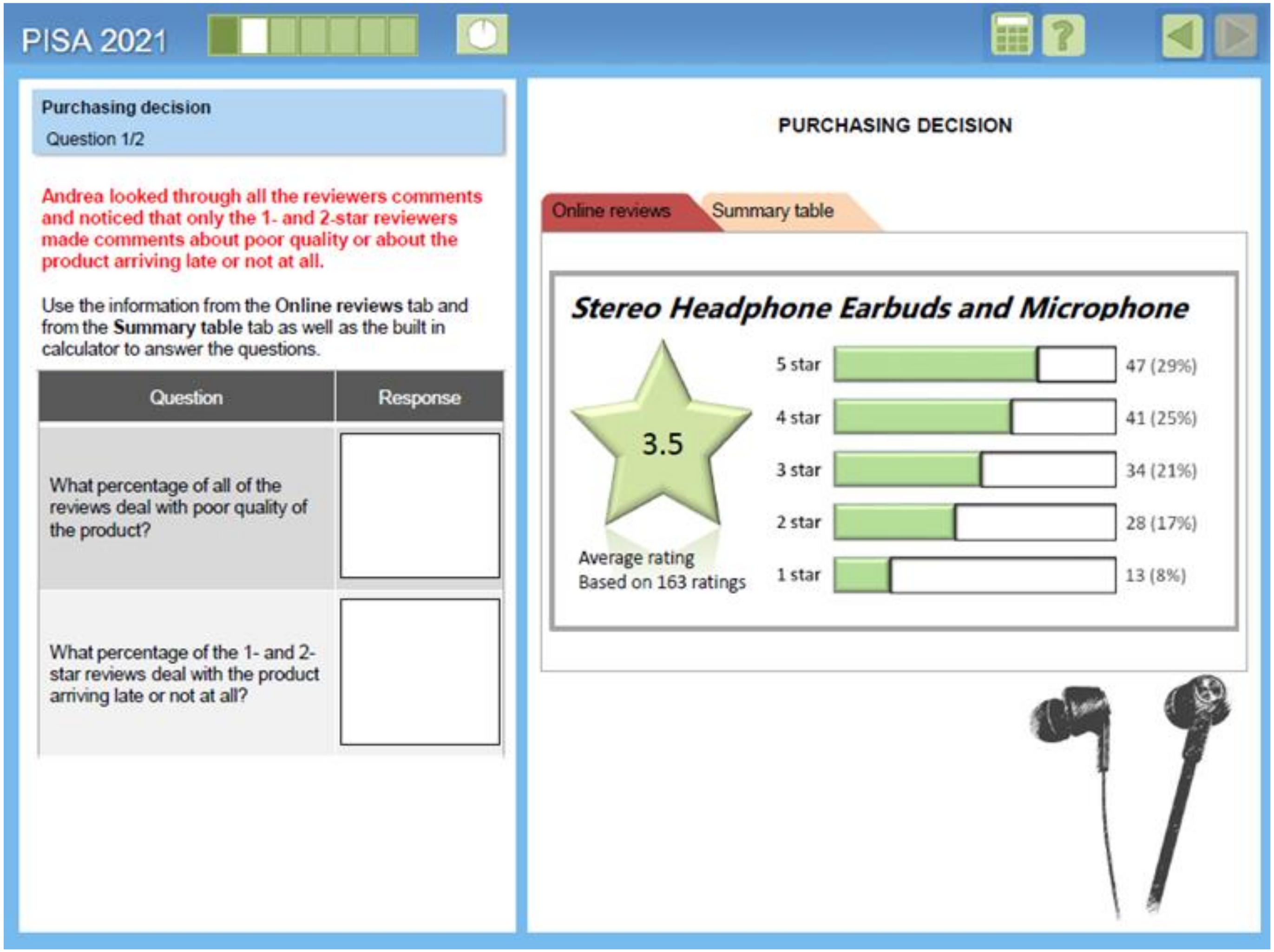


Annex Figure 2.A.22. Purchasing decision - Introduction continued

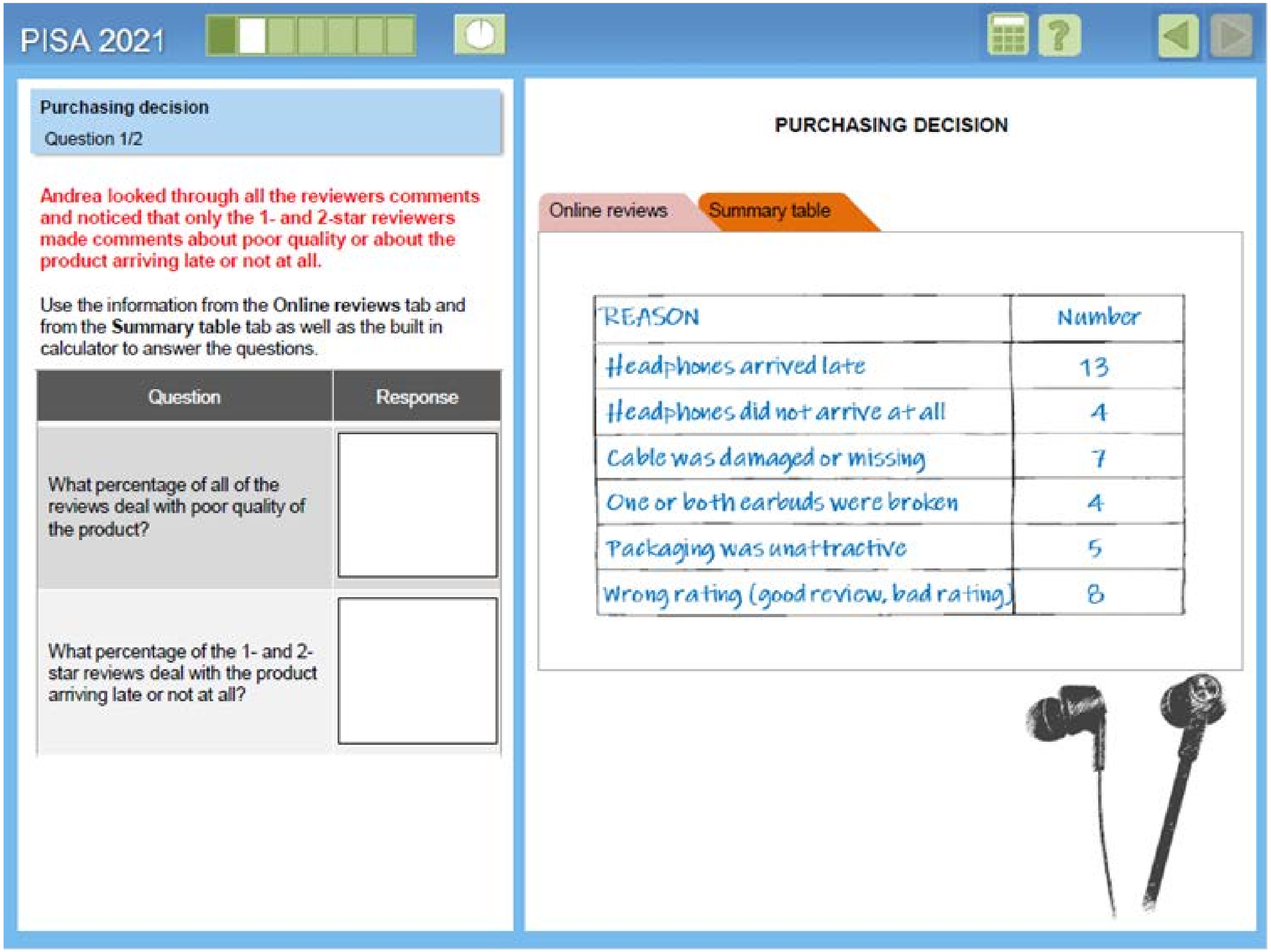


REASON	Number
Headphones arrived late	13
Headphones did not arrive at all	4
Cable was damaged or missing	7
One or both earbuds were broken	4
Packaging was unattractive	5
Wrong rating (good review, bad rating)	8

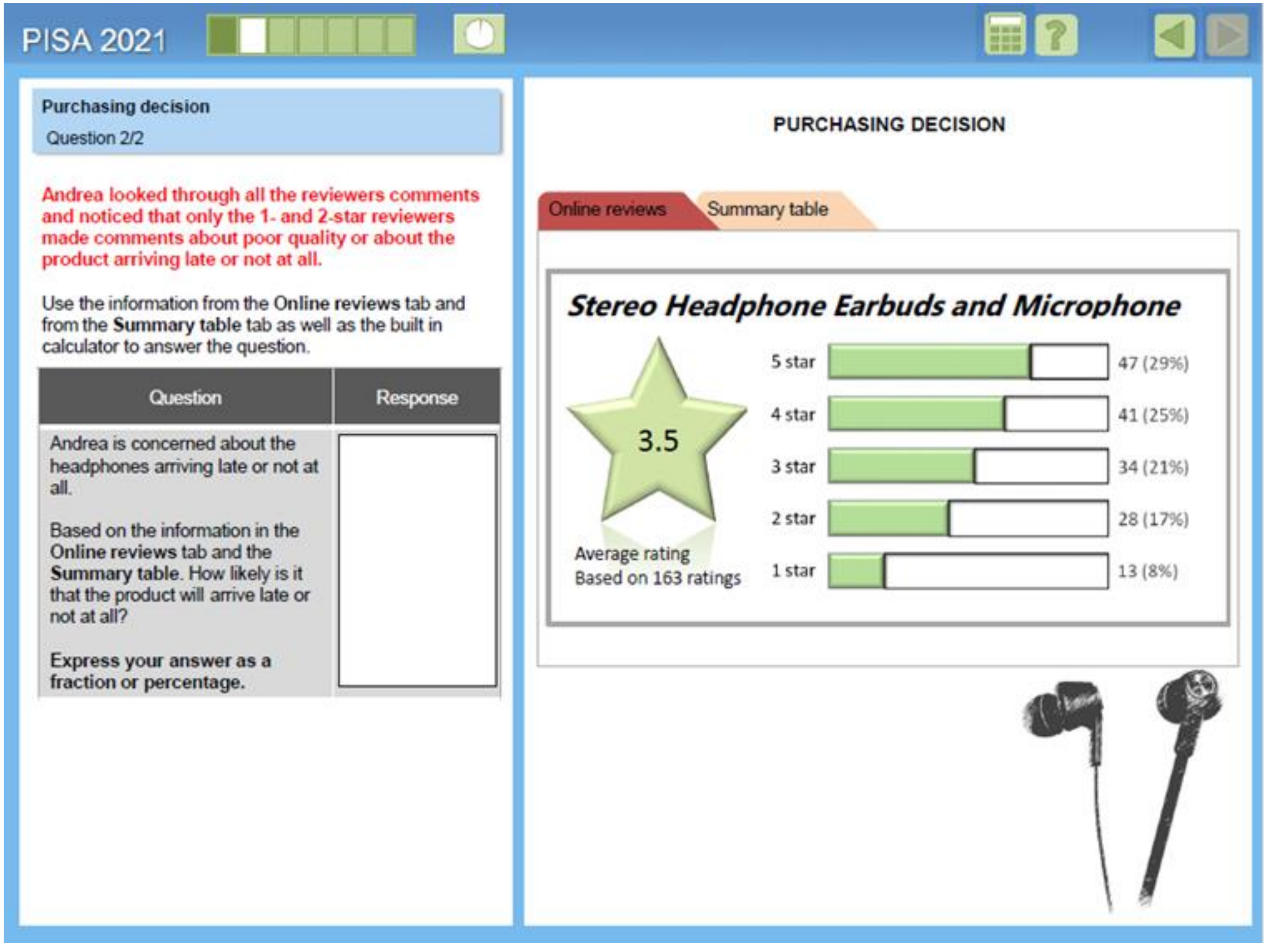
Annex Figure 2.A.23. Purchasing decision – Question 1/2 Online reviews



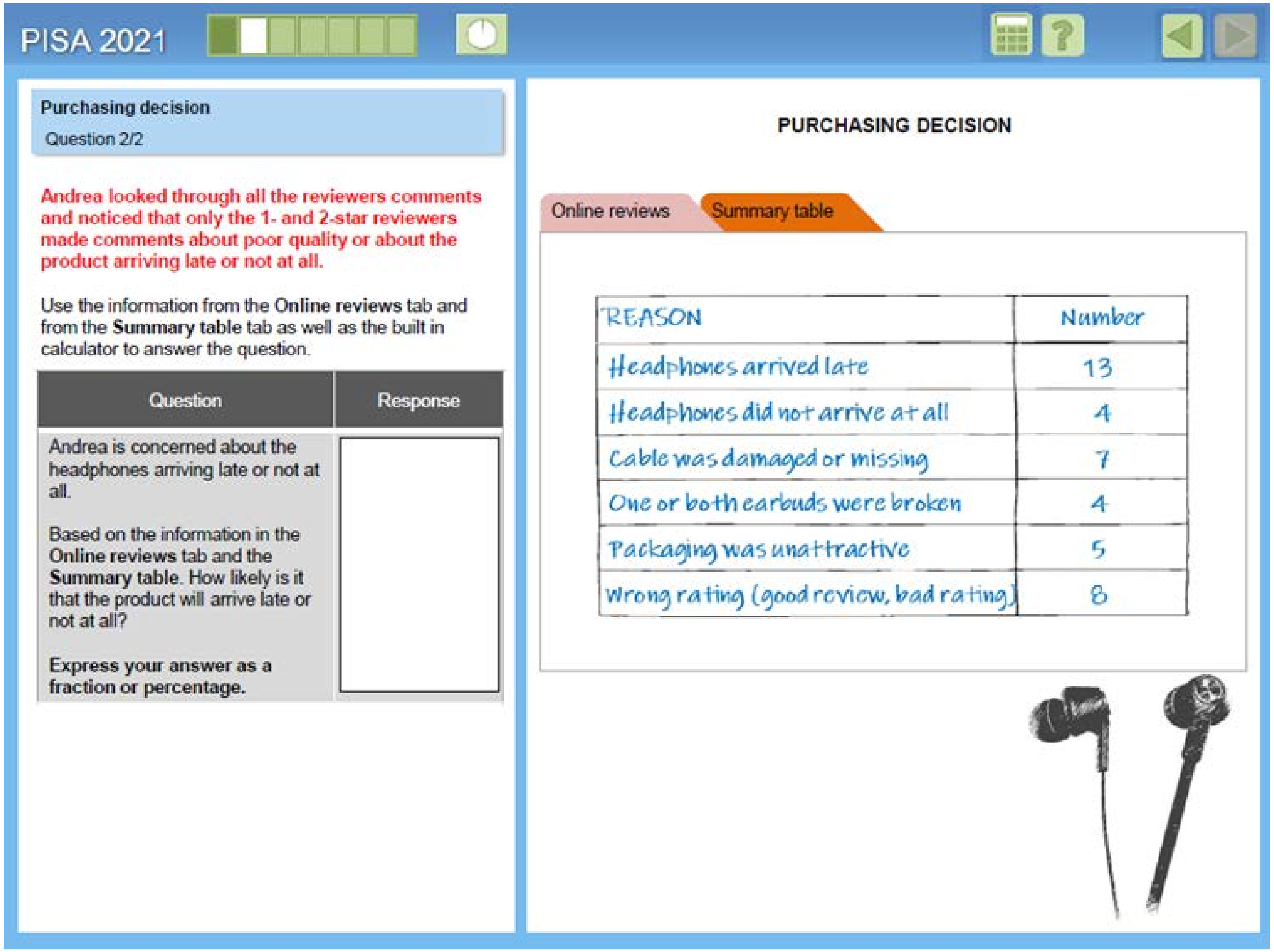
Annex Figure 2.A.24. Purchasing decision – Question 1/2 Summary table



Annex Figure 2.A.25. Purchasing decision – Question 2/2 Online reviews

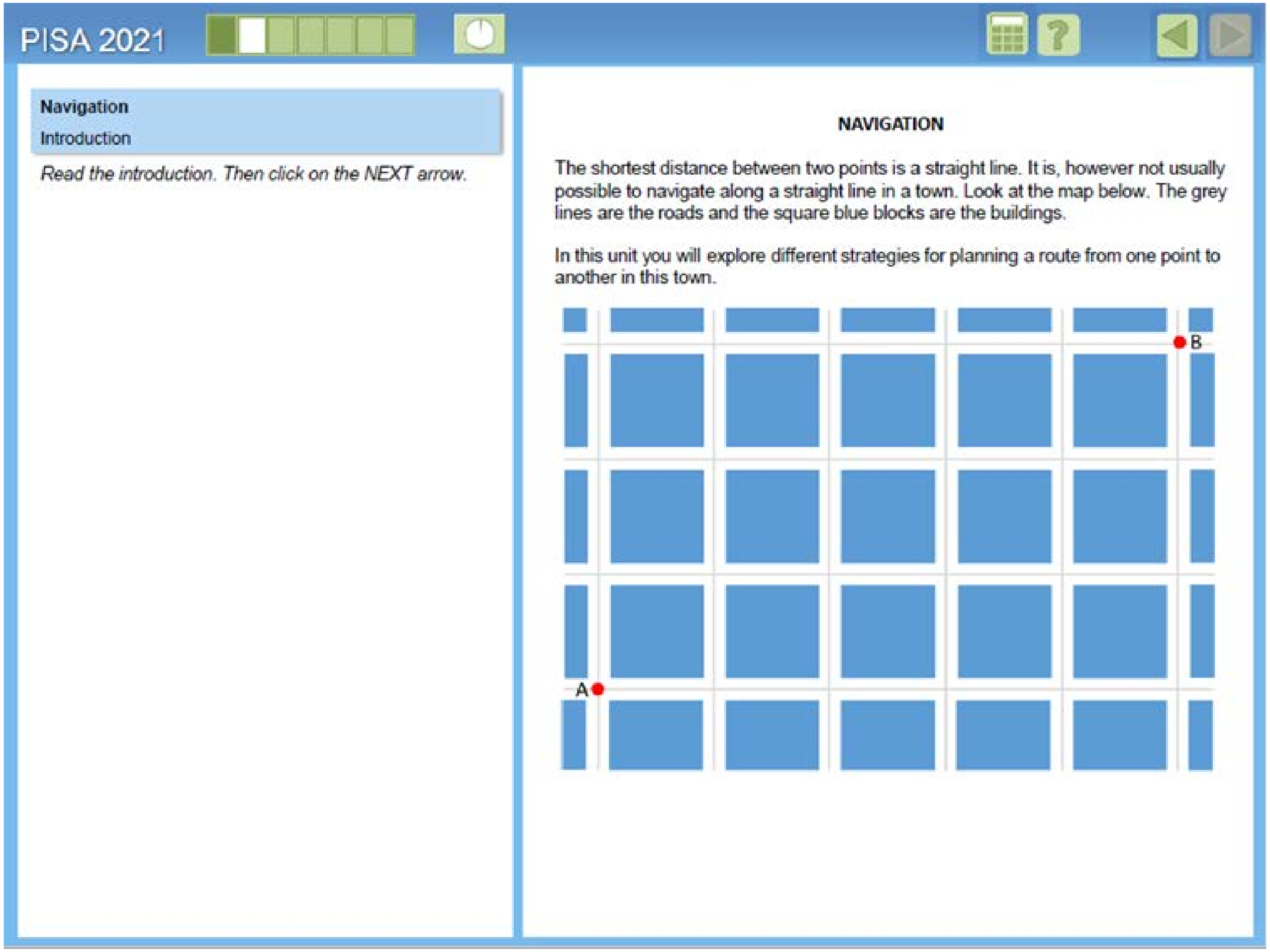


Annex Figure 2.A.26. Purchasing decision – Question 2/2 Summary table

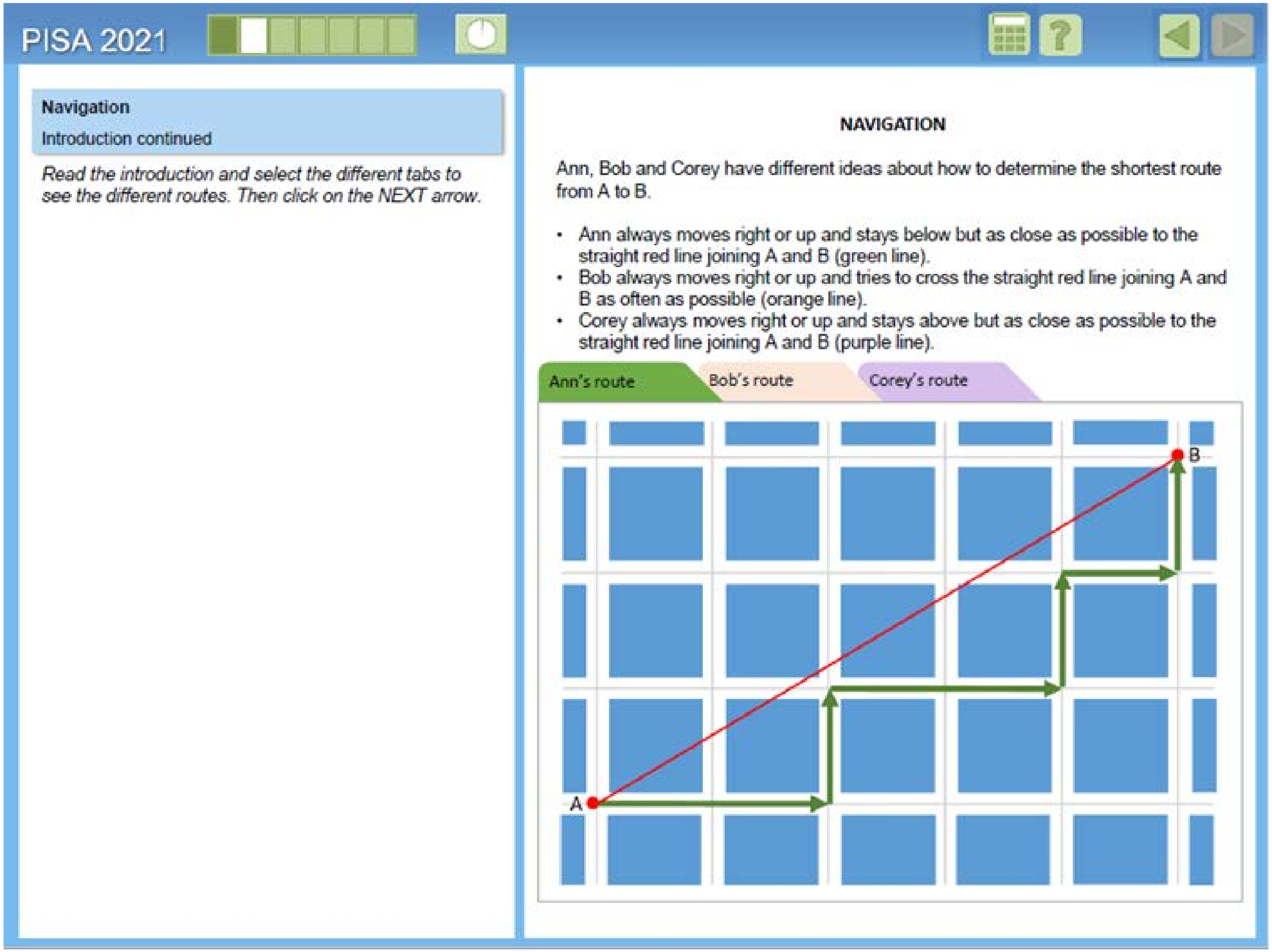


Navigation

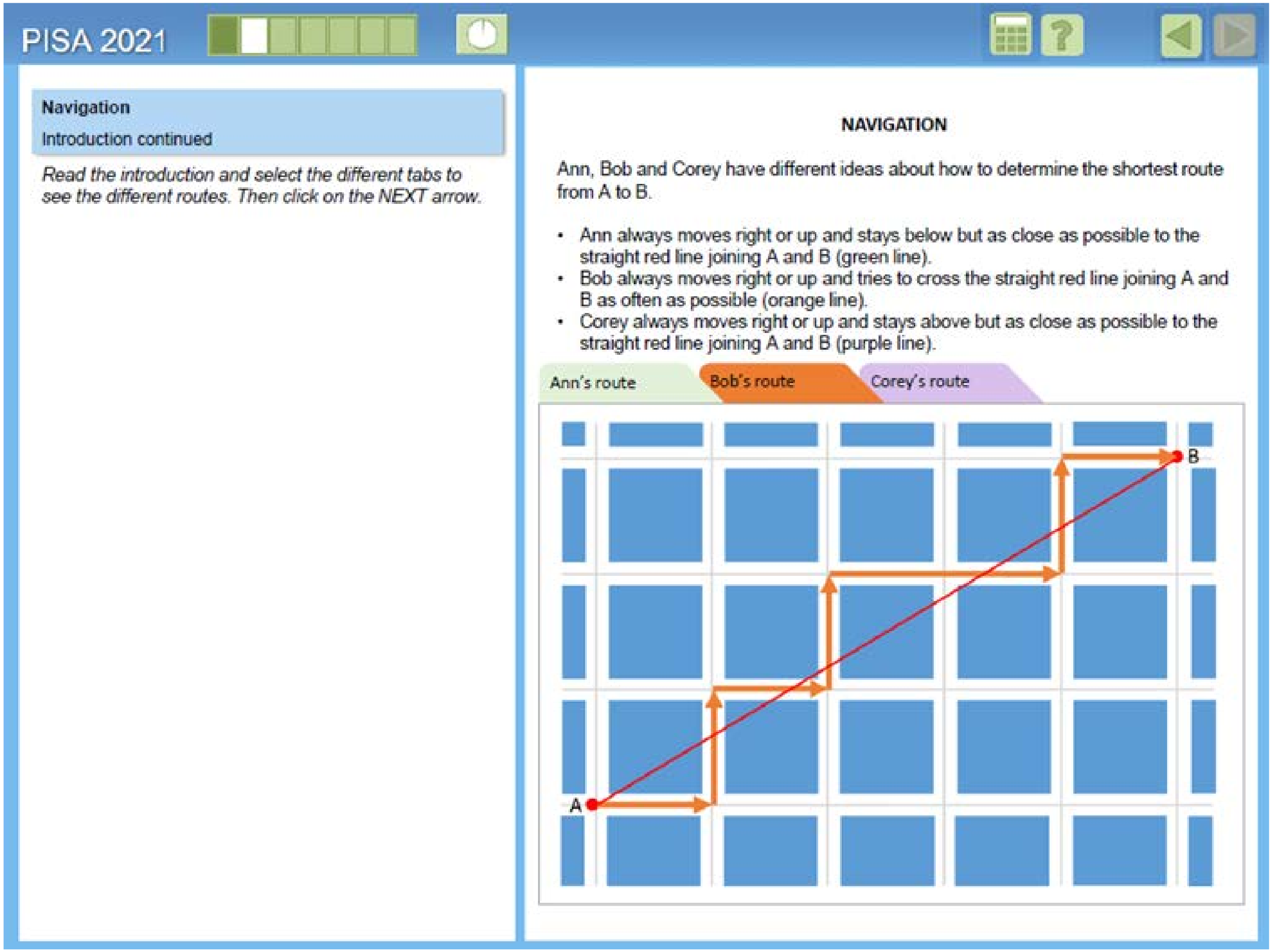
Annex Figure 2.A.27. Navigation - Introduction



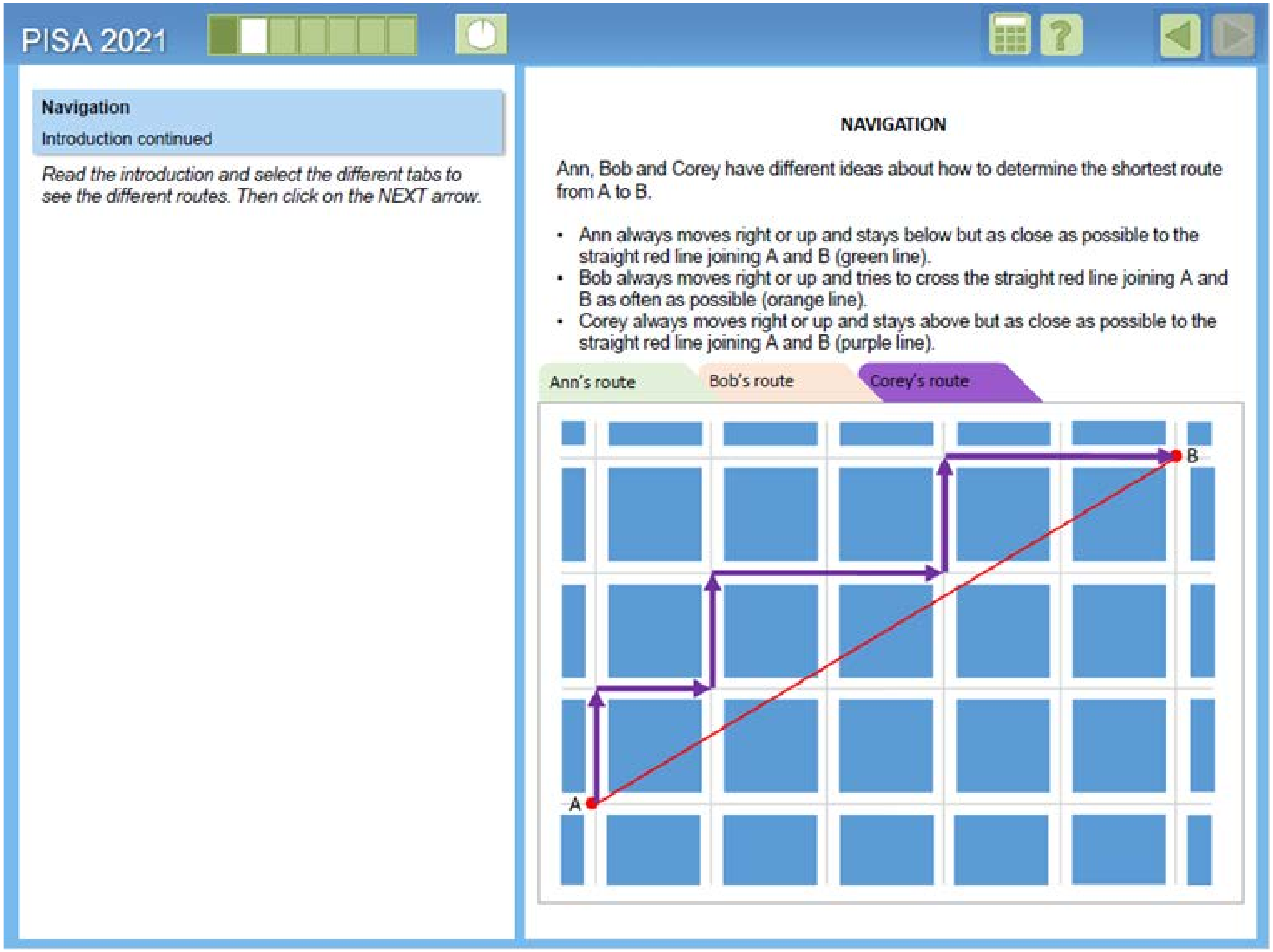
Annex Figure 2.A.28. Navigation – Introduction **continued Ann's route**



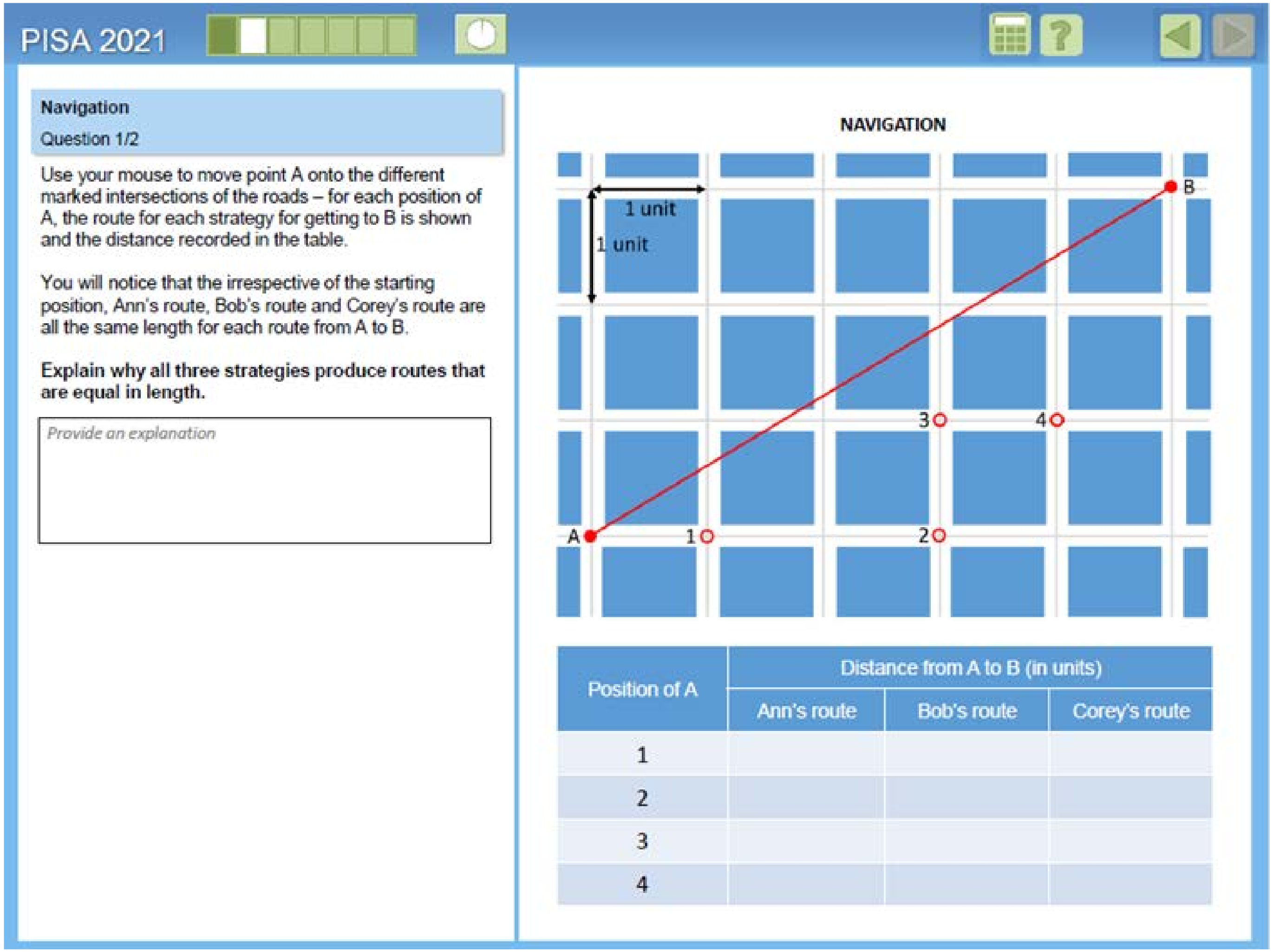
Annex Figure 2.A.29. Navigation – Introduction continued Bob's route



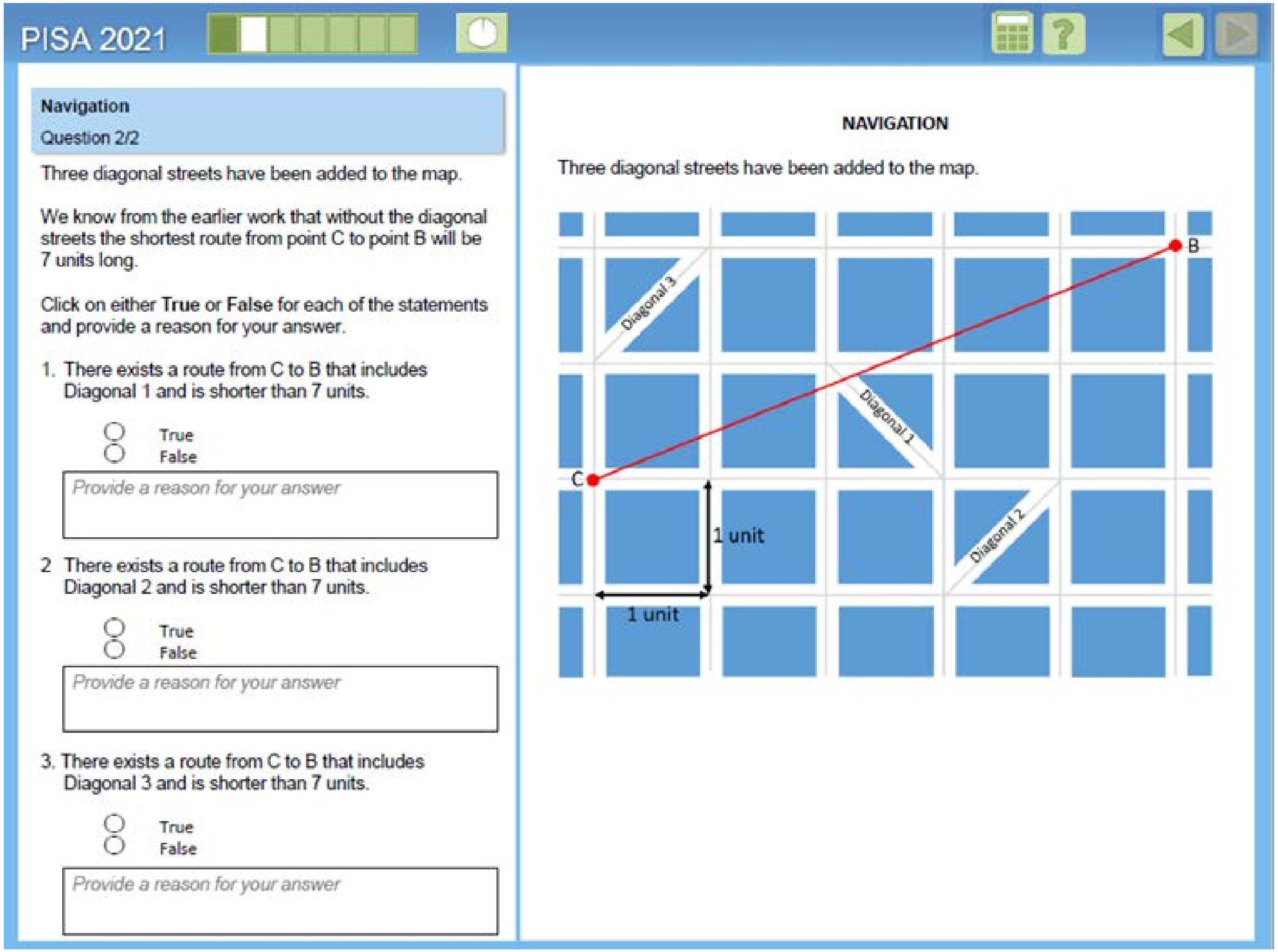
Annex Figure 2.A.30. Navigation – Introduction continued Corey's route



Annex Figure 2.A.31. Navigation – Question 1/2

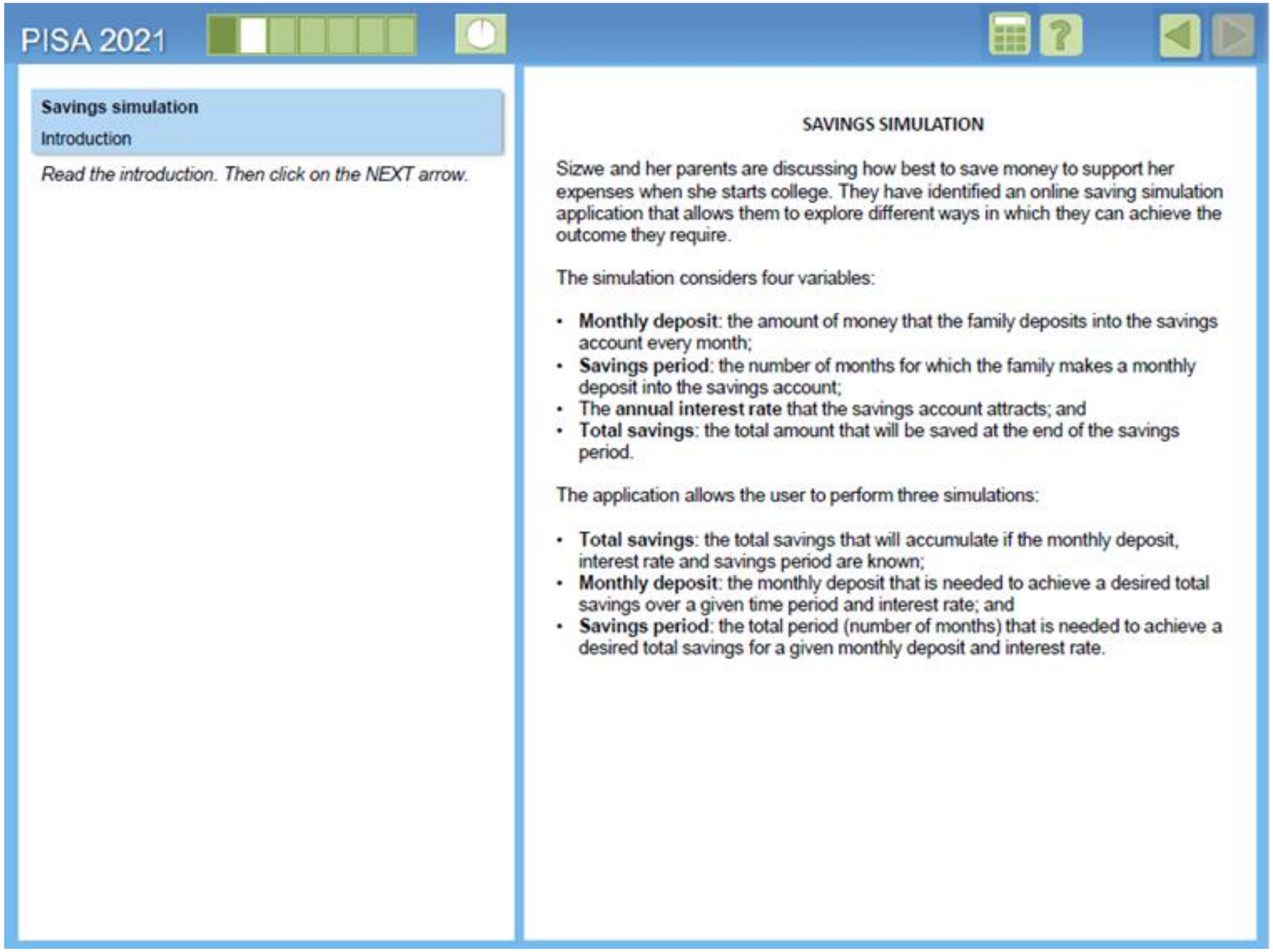


Annex Figure 2.A.32. Navigation – Question 2/2

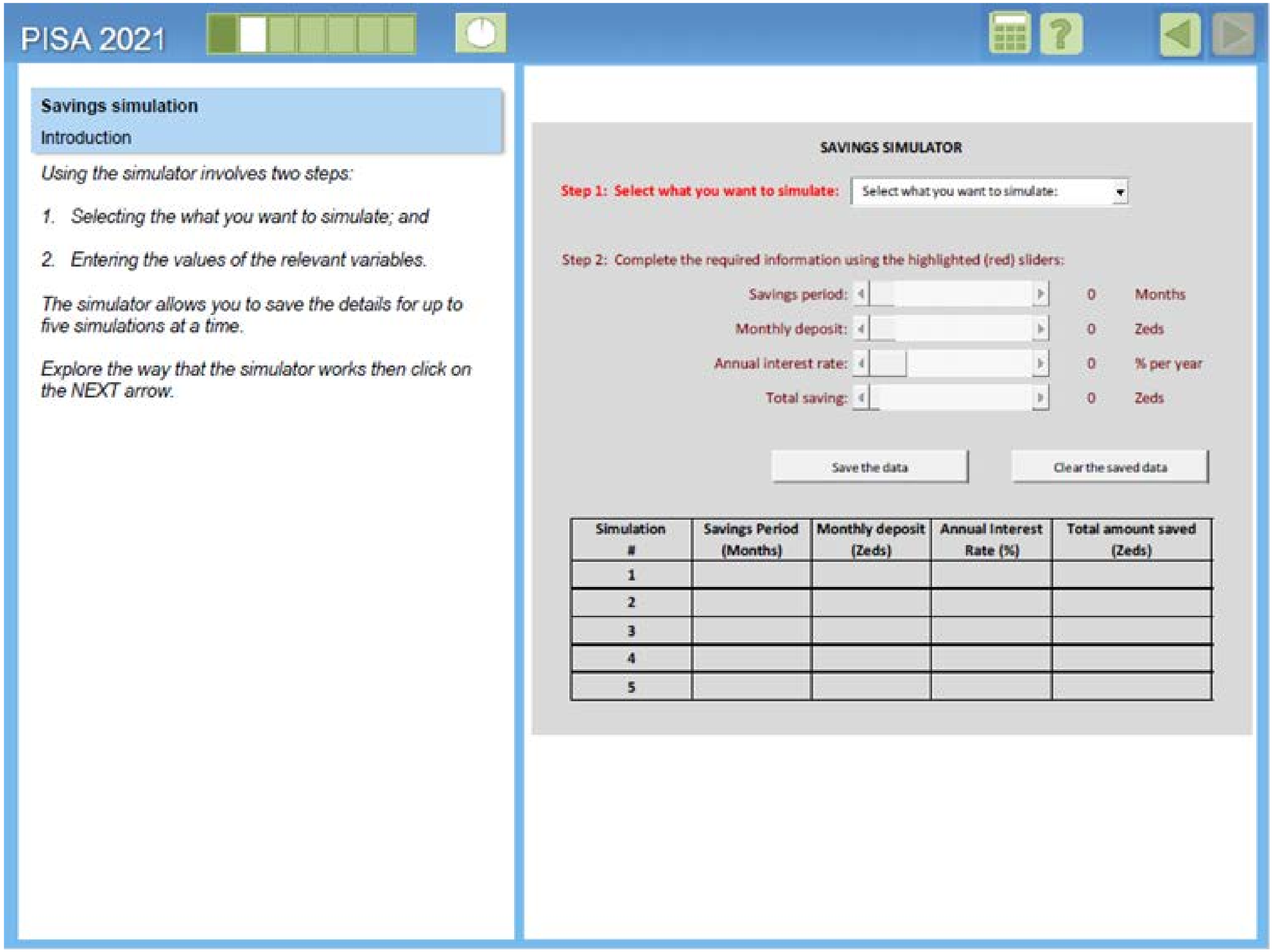


Savings simulation

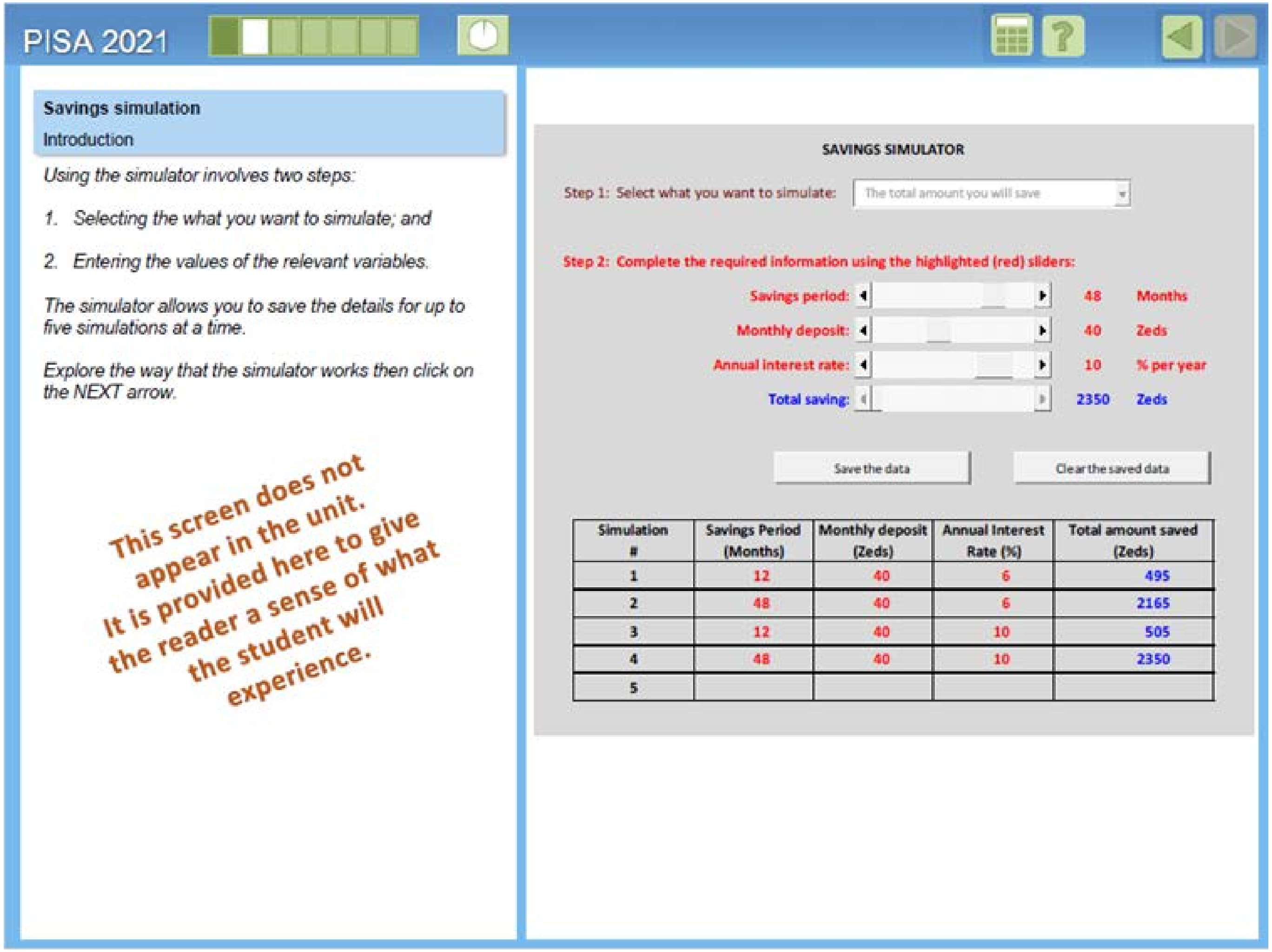
Annex Figure 2.A.33. Savings simulation - Introduction



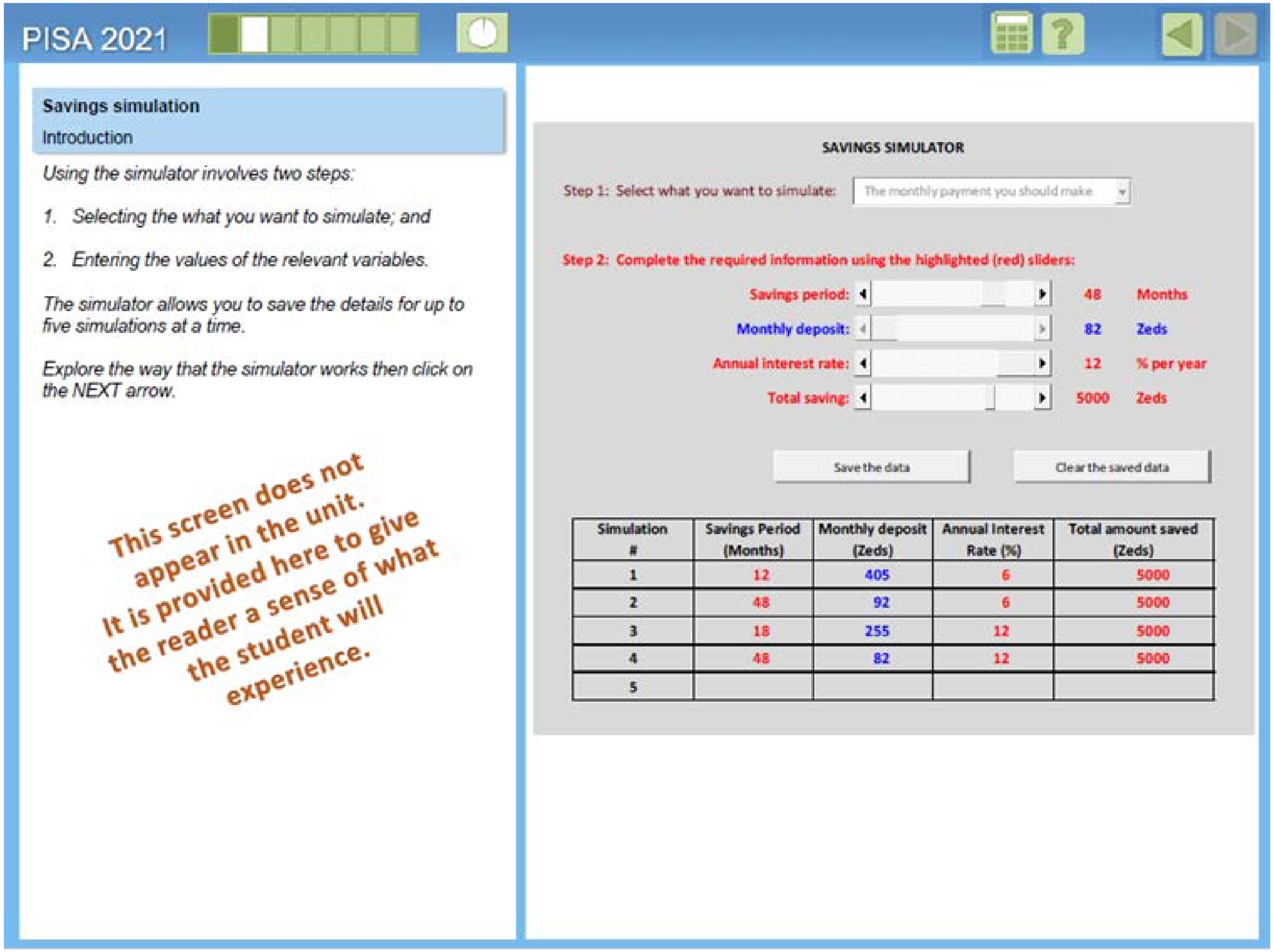
Annex Figure 2.A.34. Savings simulation – Introduction Simulator Step 1



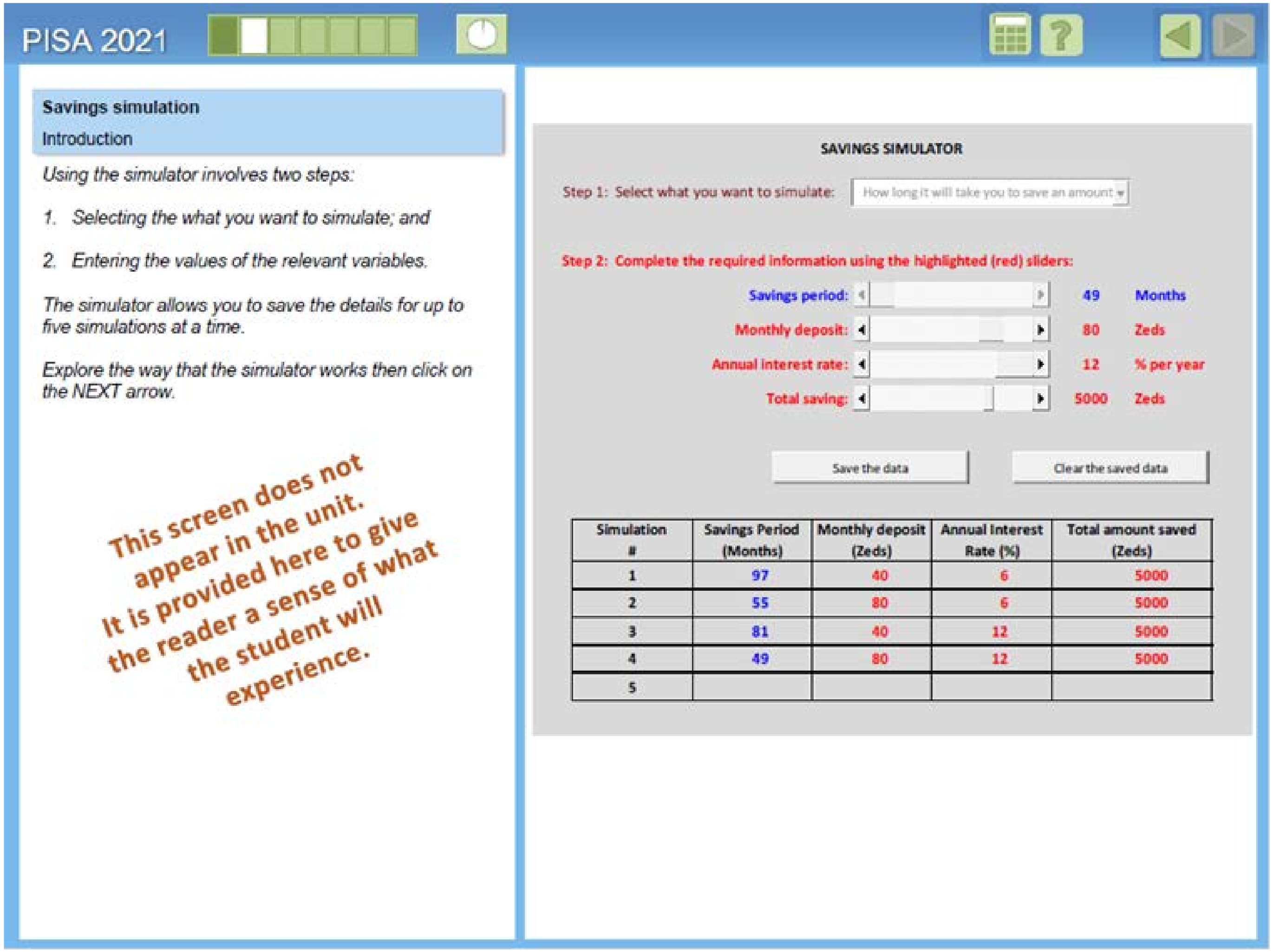
Annex Figure 2.A.35. Savings simulation – Introduction Simulator Step 2 Total saving



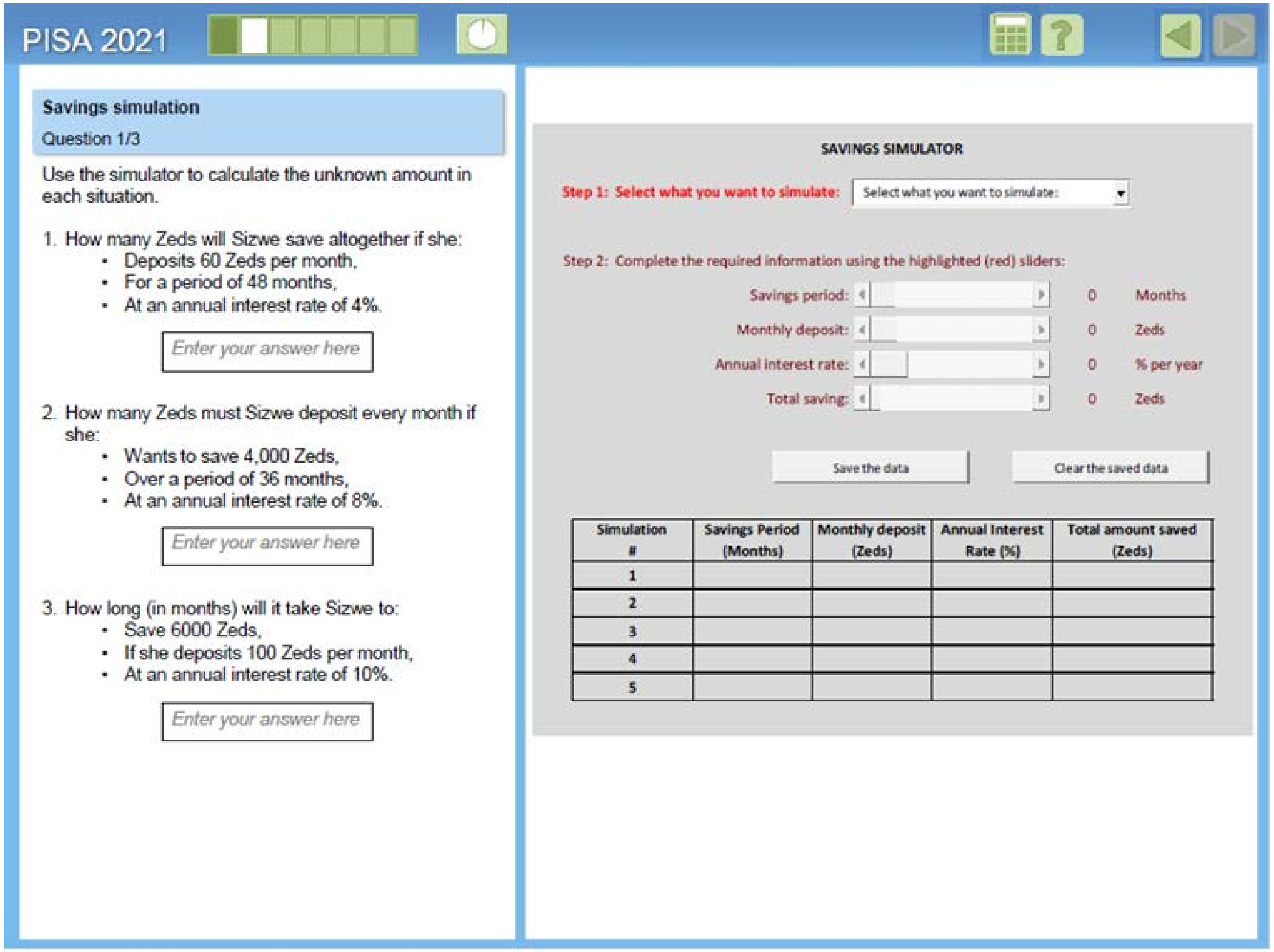
Annex Figure 2.A.36. Savings simulation – Introduction Simulator Step 2 Monthly deposit



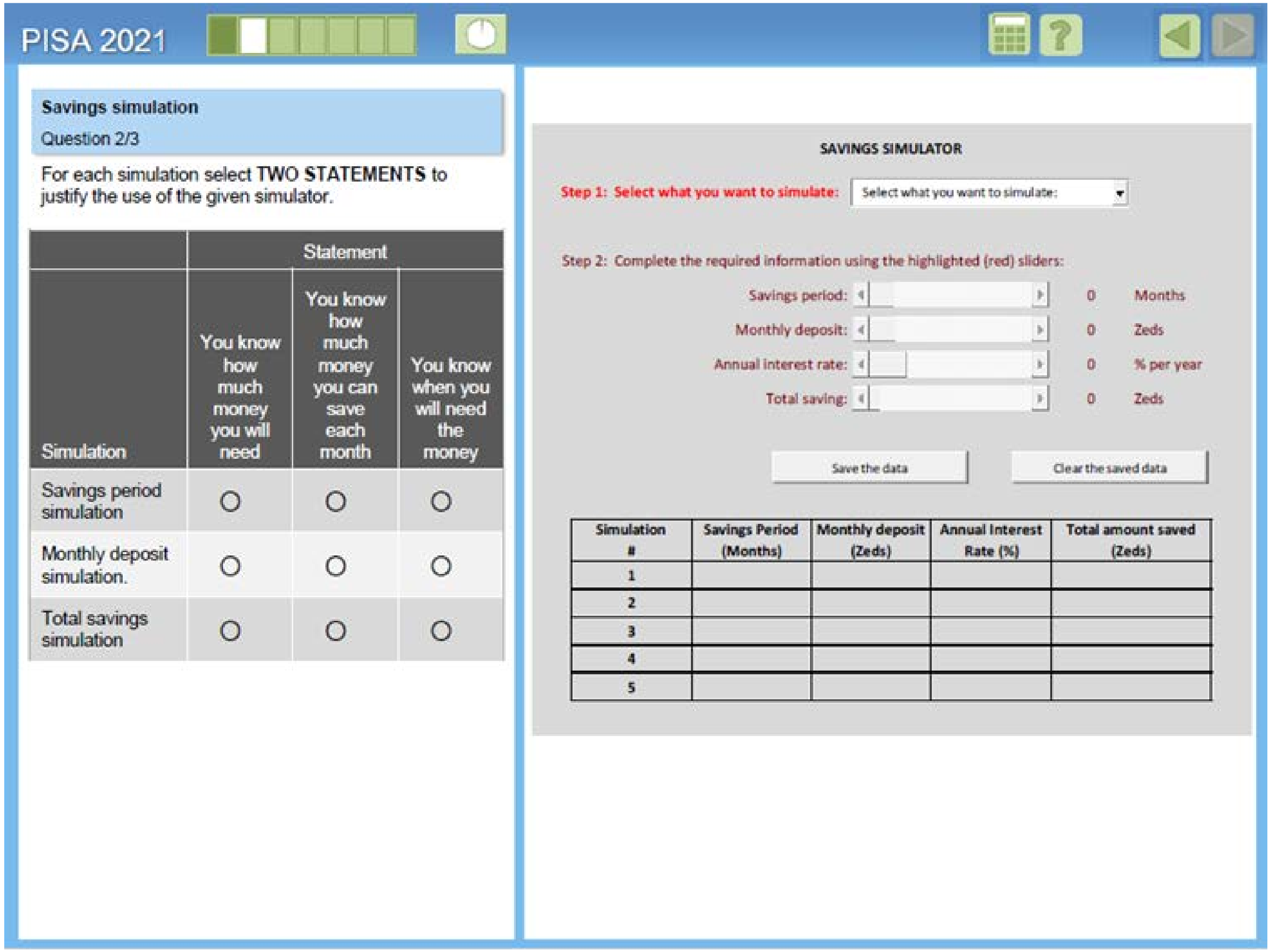
Annex Figure 2.A.37. Savings simulation – Introduction Simulator Step 2 Savings period



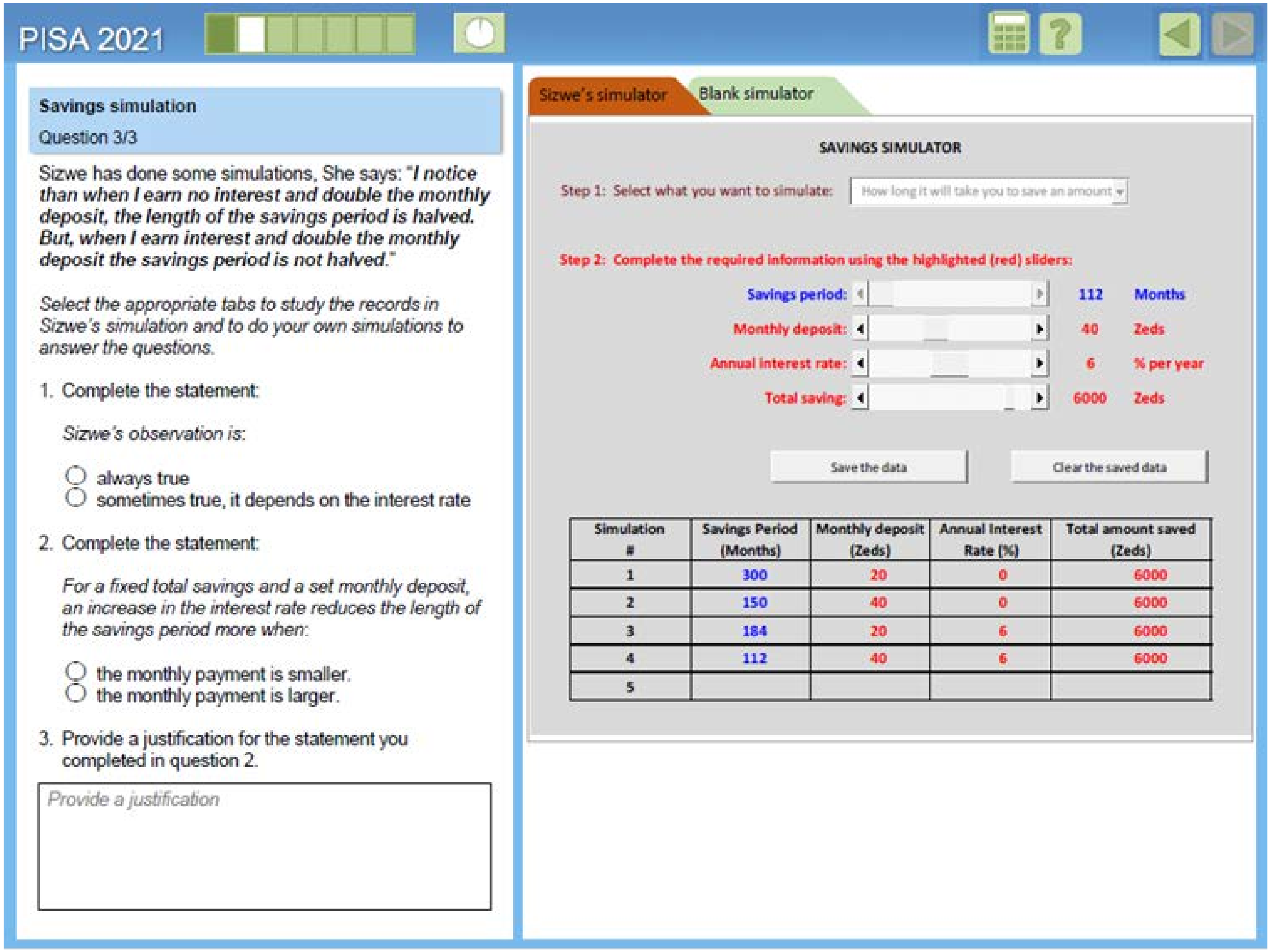
Annex Figure 2.A.38. Savings simulation – Question 1/3



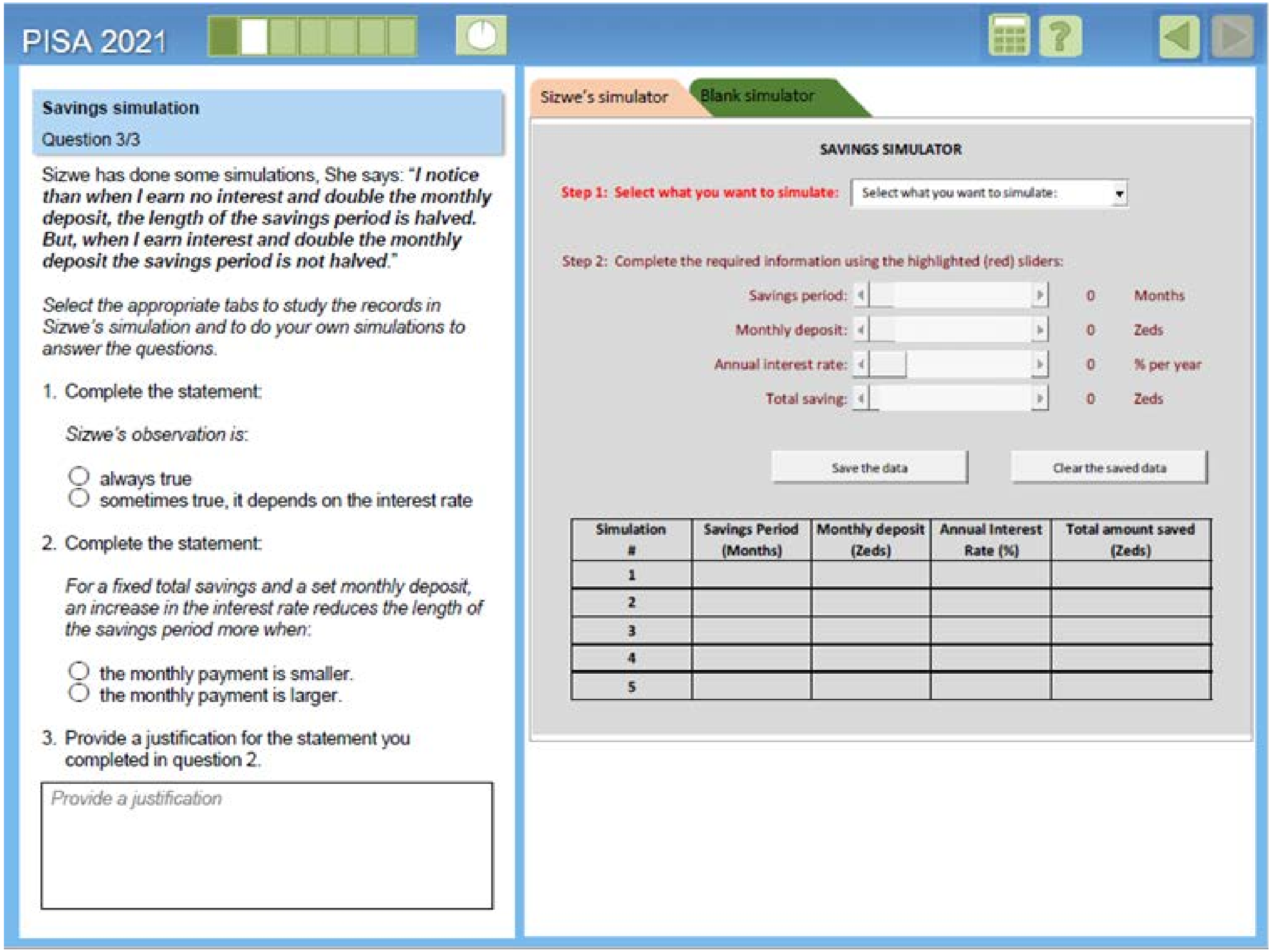
Annex Figure 2.A.39. Savings simulation – Question 2/3



Annex Figure 2.A.40. Savings simulation – Question 2/3 **Sizwe's simulator**



Annex Figure 2.A.41. Savings simulation – Question 2/3 Blank simulator



3 PISA 2022 Financial Literacy Framework

The PISA 2022 study offers an optional assessment of financial literacy for the fourth time. The revised framework proposed in this chapter takes into account changes in the socio-demographic and financial landscape that are relevant for students' financial literacy and decision making. It includes slight revisions to the PISA definition of financial literacy and to the description of the domain around the content, processes and contexts that are relevant for the assessment of 15-year-old students. As before, the framework discusses the relationship between financial literacy and non-cognitive skills, and between financial literacy and other domains of knowledge and skills.

Background

PISA 2012 was the first large-scale international study to assess the financial literacy of young people. Since 2012, the PISA financial literacy assessment has provided a unique source of evidence on the increasing engagement of young people with financial issues and on their skills to address the challenges posed by an evolving financial landscape (OECD, 2014[1]).

The OECD conducted the PISA 2022 financial literacy assessment, ten years after the first exercise. In the meantime, technological innovations, global connectivity, demographic changes and other major trends shaped society and highlighted the continued need for individuals to acquire financial competencies.

In this context, it is important that the PISA financial literacy assessment continues to remain up-to-date and relevant. This requires a comprehensive review of the assessment and analytical framework, as the key document defining the construct being measured and its practical translation into the cognitive test.

The PISA financial literacy analytical and assessment framework was first developed for PISA 2012 and has undergone only minor editorial revisions for PISA 2015 and PISA 2018. This document presents a more thorough revision for PISA 2022, as described in Box 3.1.

This framework was used to guide the development of a small number of new questions for the PISA 2022 financial literacy assessment.

Box 3.1. Main revisions with respect to the PISA 2012-2018 financial literacy framework

- The introduction has been substantially revised to take into account recent developments in the financial, economic and socio-demographic landscape that are relevant for the financial literacy of young people and that provide a motivation for this assessment; it also takes into account recent research on financial literacy and financial education.
- Revision to the definition of financial literacy (replacing "motivation and confidence" with "attitudes", to take into account the role of a broader set of attitudes).
- The descriptions of all content areas have been updated to incorporate new financial knowledge competencies needed by young people, reflecting the new trends described in the introduction.
- The process category "analyse information in a financial context" has been renamed as "analyse financial information and situations" to take into account its broader scope;
- The structure of other content, process and context categories remained the same, but the distribution of score points across the various categories has been slightly revised (Table 3.1), in order to:

  o Give slightly more weight to the "risk and reward" and "financial landscape" content areas, following the trends described in the introduction, and

  o Give slightly less weight to the process "apply financial knowledge and understanding" in order to reduce the emphasis on numerical skills in cognitive tasks.
- The descriptions of non-cognitive factors has been revised to take into account:

  o New ways in which young people can access information and education (including digital tools and delivery channels developed using behavioural insights),

  o New ways in which young people can access money and financial products (notably through digital financial services),

  o A wider set of financial attitudes that may be related to cognitive aspects of financial literacy,

  o A wider set of financial behaviours that young people may engage in.
- The section on "the interaction of financial literacy with knowledge and skills in other domains" was expanded to take into account possible future synergies with other cognitive assessments.

Introduction

PISA 2012 was the first large-scale international study to assess the financial literacy of young people, and indicated wide variations in levels of financial literacy within and across countries. The PISA 2015 and 2018 assessments provided information about trends, as well as data on additional countries joining the assessment.

The development of the PISA financial literacy assessment and analytical framework 2012 provided the first detailed guidance on the scope and operational definition of financial literacy. It provided a common language for discussion of the domain, it increased the understanding of what was being measured and promoted the analysis of knowledge and skills associated with competency in the domain, thus providing the groundwork for building the described proficiency scales that are used to interpret the results. The 2012 framework contributed to the development of national financial literacy frameworks, and offered a basis for the creation of the OECD/INFE core competencies framework on financial literacy for youth (OECD, 2015[2]) and the EU/OECD Financial competence framework for youth and children in the EU (forthcoming 2023).

The results of the existing PISA financial literacy assessments have encouraged policy makers to develop, revise or step up their financial education initiatives for young people. Some of these efforts use PISA results as a benchmark or encourage participation in the PISA financial literacy assessment as part of their national strategies for financial education, as is the case for instance in Australia, Brazil, Italy and the US (ASIC, 2017[3]; Federal Government of Brazil, 2017[4]; Italian Government, 2017[5]; Financial Literacy and Education Commission, 2016[6]). The importance of PISA financial literacy data for the policy agenda is also reflected in the EU work on sustainable finance (EU, 2018[7]).

Building on that first exercise and subsequent minor edits for the assessments in 2015 and 2018, the revised framework proposed in this document for the PISA 2022 assessment, takes into account changes in the socio-demographic and financial landscape that are relevant for students' financial literacy and decision making. It includes slight revisions to the definition of financial literacy for youth and to the description of the domain around the content, processes and contexts that are relevant for the assessment of 15-year-old students. As before, the framework discusses the relationship between financial literacy and non-cognitive skills and with other domains of knowledge and skills. Box 3.1 summarises the main revisions.

Growing policy relevance of financial literacy for young people

Over the past decades, developed and emerging economies have become increasingly aware of the importance of ensuring that their citizens are financially literate. This has stemmed in particular from shrinking public and private support systems, shifting demographic profiles including the ageing of the population, and wide-ranging developments in the financial marketplace including the increasing digitalisation of finance.

A lack of financial literacy leaves people ill-equipped to make appropriate financial decisions, which could, in turn, have tremendous adverse effects on both personal and, ultimately, global financial resilience (OECD, 2009[8]). As a result, financial literacy is now globally acknowledged as an essential life skill and targeted financial education policy is considered to be an important element of economic and financial stability and development.

This is reflected in the G20 endorsement of the OECD/INFE (International Network on Financial Education) High-level Principles on National Strategies for Financial Education (G20, 2012[9]; OECD/INFE, 2012[10]) and the OECD/INFE policy handbook on national strategies for financial education (OECD, 2015[11]). G20 leaders also recognised that this requires lifelong learning that starts in childhood, as indicated by their call for core competencies on financial literacy for young people and adults (OECD, 2015[2]; 2016[12]), and their statement supporting the widespread use of instruments to measure youth financial literacy including the PISA financial literacy assessment (G20, 2013[13]).

A series of tangible trends underpin the global interest in financial literacy as a key life skill, especially for young people. Some of these trends were relevant at the time the 2012 framework was drafted and continue to remain relevant; other trends – especially the digitalisation of finance – have become increasingly important in recent years. These are summarised below.

Trends in the financial landscape

Access to money and financial products and services from a young age

Greater financial inclusion in emerging economies, as well as worldwide developments in technology and deregulation, have resulted in widening access to all kinds of financial products. Growing numbers of consumers therefore have access to financial products and services from a variety of established and new providers delivered through traditional and digital channels, including traditional financial institutions, online banks and mobile phone companies. Whilst many of the products available bring advantages and help to improve financial well-being, many are also complex and pose new challenges or risks.

Young people and children increasingly have access to financial products and services. Data from the PISA 2012, 2015 and 2018 financial literacy assessments revealed that many 15-year-old students hold bank accounts and prepaid debits cards (as these students are minors cards and accounts are typically opened with the consent of a parent or guardian). In 2015, on average across the 10 participating OECD countries and economies, 56% of students held a bank account. In Australia, the Flemish Community of Belgium, the participating Canadian provinces and the Netherlands, more than seven in ten students held a bank account (OECD, 2017[14]). In some countries, like China, the Netherlands, Russia and the UK, children as young as five or six can use debit cards linked to their parents' accounts (Imaeva et al., 2017[15]). Such access could potentially provide young people with the opportunity to gain practical experience with parental oversight, assuming the basic prerequisite of a financial landscape with robust regulation and financial consumer protection.

Even when they do not formally have an account or card, many young people have access to money in the form of gifts, pocket money and wages from part time and/or informal jobs. PISA 2015 data shows that on average across 10 participating OECD countries and economies, 64% of students earn money from some formal or informal work activity, such as working outside school hours, working in a family business, or doing occasional informal jobs. More than one in three students, on average in each of the 15 participating countries and economies, reported that they receive money from an allowance or pocket money for regularly doing chores at home (OECD, 2017[14]).

PISA data also shows that in some countries access to a financial product is positively associated with financial literacy performance. According to PISA 2015 data, in Australia, the Flemish Community of Belgium, the participating Canadian provinces, Italy, the Netherlands, Spain and the United States, students who held a bank account performed better in financial literacy by over 20 score points than students of similar socio-economic status who did not have a bank account (OECD, 2017[14]). Evidence that there is a positive relationship between performance in financial literacy and holding a bank account or receiving gifts of money may suggest that some kind of experience with money or financial products could provide students with an opportunity to reinforce financial literacy, or that students who are more financially literate are more motivated to use financial products – and perhaps more confident in doing so. Parents are very likely to be involved in these experiences, as they may have given their children money through allowances or gifts, opened a bank account for them and taught them how to use it.

It is important that young people begin to know their rights and responsibilities as current or future financial consumers. They also need to start to understand the risks associated with the different products and services as well as their potential benefits when used appropriately, even before they acquire full legal rights to enter into financial contracts by themselves.

Widespread emergence of digital financial products and services

Recent years have seen a rapid increase in technological innovation and in the application of digital technology across a number of spheres. Internet access has grown around the world and smart phones provide ubiquitous connectivity. Large parts of the world's population are increasingly using digital technologies not only to communicate but also to access and use financial services.

Digital financial services include any financial operation using digital technology, such as electronic money, mobile financial services, online financial services, i-teller solutions, and branchless banking. They are a major global phenomenon and are widespread in both the developed and developing world (EY, 2017[16]; GSMA, 2018[17]). The share of digitally active adult consumers using FinTech services on a regular basis went from 16% in 2015 to 33% in 2017 on average in six economies (Australia, Canada, Hong Kong China, Singapore, UK, US) (EY, 2017[16]). Young people are particularly active users of digital financial services. On average in 20 economies, 37% of 18-24 year-olds and 48% of 25-34 year-olds who are digitally active use FinTech services on a regular basis (EY, 2017[16]). In Canada, one half of youth 25-34 years old conduct transactions on the Internet at least weekly, almost twice as many as older Canadians (Statistics Canada, 2018[18]).

Digital financial services offer great possibilities for integrating the poor and previously financially excluded populations into the formal financial system by overcoming physical infrastructure barriers, lowering costs, offering faster and timely transactions, and potentially providing a seamless experience tailored to individual needs. At the same time, however, the spread of digital innovation in finance has created new sources of risk for consumers, including new types of fraud and risks related to the security and confidentiality of data. Legitimate use of consumer data to create digital profiles may also make it more costly or difficult to access certain types of financial products or services as financial service providers seek to segment their consumer base and price or market their products accordingly. Moreover, digital channels and questionable digital market practices have made access to some products – like high-cost short-term credit – extremely rapid and may reinforce behavioural biases, like short-termism and lack of self-control (OECD, 2017[19]).

Some of these risks are particularly relevant for children and young people, typically stemming from the fact that they are at ease with digital technologies and are often users of social media and other digital tools, while at the same time potentially having low financial literacy and little experience with financial services. Recent evidence from the US shows that Millennials using mobile phones to make payments tend to display lower financial knowledge and more problematic financial behaviours (overdrawing their current accounts, using credit cards expensively, or using high-cost borrowing methods) than non-mobile-payment users (Lusardi, de Bassa Scheresberg and Avery, 2018[20]), suggesting that technology and ease of payments may attract disproportionately those who have low financial literacy and manage their finances poorly.

The rapid evolution of digital financial services also means that parents themselves may have little familiarity with them and limited ability to guide their children. Moreover, as young people are typically new entrants in traditional and digital financial markets, financial regulation may find it challenging to address their needs and protect them. As the financial landscape evolves, new types of institutions, services and products may emerge, making these challenges more acute.

The large availability of cashless purchasing options through online stores, interactive television, online and mobile games, social media, or with contactless cards may make money less real for users making their first spending decisions. As young people can feel under pressure to spend to keep up with their peers, many digital channels enable users to make instant purchases, which in turn makes it more difficult to control spending. In some digital contexts, young people may not even realise that they are spending real money, as in the case of in-app or in-game purchases that may be linked to automatic withdrawals through a monthly telephone or internet bill or a credit card account. While in many countries issues related to in-game expenses have been addressed by financial regulation, it is also important that parents and children are alert in their online behaviour.

Young people are the most active users of social media. Around 90% of 18-29 year olds in the US, and of people age 16-24 in the European Union, use some form of social media (EU, 2017[21]; Perrin, 2015[22]), potentially bringing them into contact with information, marketing and consumer opinions. They may have a hard time distinguishing the source and accuracy of information posted on such platforms, and may succumb to behavioural biases when reading the same (mis)information from numerous sources. They may also be unaware that their data can be used to create digital profiles that are then used or sold to third parties to promote products or price them according to their personal characteristics.

Many young people also fall victims of fraud and scams with financial implications via social media, such as becoming prey to identity theft, following fraudulent offers to invest, or even, knowingly or unknowingly, allowing their personal bank accounts to be used for illicit purposes (Cifas, 2018[23]; Startup, Cadywould and Laza, 2017[24]). A study conducted by the FCA in the UK found that those aged under 25 (13%) were six times more likely than over 55s (2%) to trust an investment offer they received via social media (FCA, 2018[25]).

Despite being digital natives, young people may be more likely to be victims of online fraud because they take risky behaviours online. A survey conducted in 17 countries in 2017 showed that young people are very likely to share personal information online. More than 60% of those aged 16-24 and 25-34 shared private and sensitive photos of themselves with others; two-fifths of young people shared their financial and payment details (42% of 16-24 year olds and 46% of 25-34 year olds) (Kaspersky, 2017[26]).

Young people are often the target of aggressive marketing practices promoting high-cost short-term online credit. For instance, in the UK and the US some online payday loans platforms target university students, in some cases offering loans secured against income from future student loan payments. Students are often not aware of the very high interest rates and possible late fees, and do not think about looking for cheaper alternatives. Some 6% of 18-24 year old people in the UK used one or more forms of high-cost loan in 2017, and this age group accounted for about one in five of all those who had used payday lending or a pawnbroker (FCA, 2017[27]). While consumers of all ages should be adequately protected via financial regulation, it is clear, considering the pace of financial markets developments, that they also need to have the knowledge and skills to understand the products on offer, be alert to financial conditions that may be unfamiliar or not be clearly stated, and compare products and providers.

Demographic and socio-economic trends

Risk shift and increased individual responsibility

A number of demographic, socio-economic and technological trends imply a transfer of risk to individuals, greater individual responsibility for many financial decisions, and greater economic insecurity for young people and future generations.

Economic trends following the global financial crisis, technological change and globalisation are likely to make economic and job prospects for future generations more uncertain (OECD, 2017[28]; Dolphin, 2012[29]). Youth unemployment rates rose substantially in most OECD countries and in a number of emerging economies after the global financial crisis, and in many cases they remain at high rates. The crisis exacerbated issues of labour market segmentation in some countries, with an increase in the proportion of employed youth working in temporary and precarious jobs as they are unable to find a permanent job. In the aftermath of the global financial crisis, disposable income has fallen more for young people than for adults and the elderly, and young people face higher poverty rates than other age groups (OECD, 2013[30]; 2017[31]; 2016[32]).

Moreover, continuing trends of increasing longevity, falling birth-rates, and shrinking public support systems in many countries have implications on people's income security during the active life and in old age.

Women's participation in the labour force and the proportion of people entering higher education are both increasing, and adults are less likely to continue to live in close proximity to their older family members than previous generations. The likely outcome of these shifts will be a greater need for financial security in retirement and professional care in old age, resulting in the need for direct financial support from family or additional government expenditure (Colombo et al., 2011[33]). Working-age adults will be expected to shoulder any tax burden to finance this expenditure whilst at the same time also saving for their own retirement, potentially repaying their own student loans, supporting their children's education and managing increasingly varied working-life trajectories which may include periods of inactivity, self-employment or retraining.

In addition, there has been a widespread transfer of risk from both governments and employers to individuals, meaning that now many people face the financial risks associated with longevity, investment, out-of-pocket healthcare and long-term care. The number of financial decisions that individuals have to make, and the significance of these decisions, is increasing as a consequence of these changes in the market and the economy. For instance, individuals will need to accumulate savings to cover much longer periods of retirement than previous generations, while at the same time covering the heightened long-term health care needs of elderly relatives. Young people are now more likely to have several employers in the course of their working lives than their parents and to experience more precariousness in the labour market. This could make it more difficult for them not only to secure a steady income flow during their working lives but also to ensure that this translates into a stable retirement income.

Traditional pay-as-you-go (PAYG) public pension schemes tend to be shrinking in most countries and are increasingly supplemented by private funded schemes in which the individual may be responsible for making investment decisions, including the contribution rate, the investment allocation and the type of pay out product. Moreover, defined-contribution pension plans are quickly replacing defined-benefit pension plans for new entrants, shifting onto workers the risks of uncertain investment performance and of longer life expectancy. Surveys show that a majority of workers are unaware of the risks they now have to face, and have neither sufficient financial knowledge nor the skills to manage such risks adequately (OECD, 2016[34]).

In this panorama of increasingly difficult financial choices, consumers need to know when and where to seek professional help. But professional advisors are not an alternative to financial education. Even when individuals use the services of financial intermediaries and advisors, they need to understand what is being offered or advised, and they need the skills and knowledge to manage the products they choose. They should also be aware that some advisors may face a conflict of interest as they provide advice and at the same time sell products or receive commission, and that "robo advice" is not necessarily more independent than advice in person. Depending on the national legal framework for financial advice, individuals may be fully responsible for the financial product they decide to purchase, facing all the direct consequences of their choice.

Changes in individual financial responsibility and choices are also underpinned by the recent increasing interest at policy and individual level for sustainable development, responsible consumption and inequalities reduction (United Nations, 2015[35]). European governments are looking into ways to ensure that the financial systems contributes to sustainable and inclusive growth (EU, 2018[7])A growing number of consumers and investors have become concerned about the sustainability and ethics of their spending choices and focus on environmental, social and governance (ESG) factors in their investment decisions. In this context, it important that individuals understand the impact of their financial choices and investments on the economy, society and the environment, that they are aware of new products following ESG criteria and of any potential emerging risk associated with these products.

Financing higher education

Students nearing the end of compulsory education will soon be taking decisions that will have significant consequences for their adult lives, such as deciding whether to continue their studies or whether to enter the labour market. The gap in wages between college and non-college educated workers has widened in many economies (OECD, 2016[36]). In some countries, this decision also includes how to finance tertiary education and whether to take a student loan.

Financing higher education requires students and their families to consider and chose among various available options, including in which university and city to study and live, deciding whether to use savings, if any, understanding the advantages and disadvantages of working while studying, and potentially taking up a loan. In some countries, like the US, student loans are becoming a more important part of young people finances than in the past, with the combined federal and private student loan debt reaching roughly $1.4 trillion in 2016 (Ratcliffe and McKernan, 2013[37]; CFPB, 2017[38]).

Countries differ significantly in the extent to which student loans are offered and used, and in how they work. Depending on national student loans characteristics, students intending to take a loan may have to choose between public and private loans and between different repayment methods. Some loans may benefit from public guarantees, reduced interest rates, favourable repayment system or remission/forgiveness mechanisms. The take-up of student loans and extent of indebtedness at graduation are quite sizeable in some countries. Even looking only at public student loans, almost eight in ten students in Australia and more than nine in ten students in the UK at bachelor's, master's or doctoral levels had one in 2013/14; in the United States, 62% of bachelor's-degree students had a public student loan in the same period (OECD, 2016[36]). As a result of taking loans, most students are in debt at graduation. Students with a loan graduate with an average debt of about USD 18 000 in the Netherlands, and of about USD 12 000 in Canada (OECD, 2016[36]). The US Consumer Financial Protection Bureau (CFPB) estimated that more than 1.2 million borrowers defaulted in 2016 (CFPB, 2017[38]).

The extent to which student loans can cause a problem mostly depends on the amount of debt, the uncertainty of graduates' earnings and employment prospects, and the conditions for repayment of the loans. If they decide to take a loan, students and their families need to be proficient in financial literacy to select the best arrangement given the family/student situation and to avoid over-indebtedness from a young age.

In some countries, like Australia, greater student responsibility for funding one's studies has been observed not only at university level but also in post-secondary vocational education (Noonan and Pilcher, 2018[39]). The recent Australian experience has seen a dramatic increase in vocational students' debt, which can be attributable to a combination of legislative changes, aggressive course offering practices, and students' lack of understanding of the debt obligations they were taking on (Commonwealth of Australia, 2016[40]).

Expected benefits of financial education and improved levels of financial literacy

Research shows that people form financial habits, skills and behaviours since childhood and adolescence, learning from their parents and others around them, indicating the importance of early interventions to help shape beneficial behaviours and attitudes (Whitebread and Bingham, 2013[41]; CFPB, 2016[42]). Furthermore, young people need financial knowledge and skills from an early age in order to operate within the complex financial landscape they are likely to find themselves in, often before reaching adulthood. Younger generations are not only likely to face complex financial products, services and markets, but as noted above, they are more likely to have to bear more financial risks in adulthood than their parents and may face new financial risks as they use digital financial service and digital tools more broadly.

Young people may learn beneficial behaviours from their friends and family, such as prioritising their expenditure or putting money aside for a rainy day, but the recent changes in the financial marketplace and social welfare systems mean it is unlikely that they can gain sufficient information, knowledge or skills from such people unless they work in related fields[1]. Moreover, not all families are equally equipped to transmit financial literacy skills to their children (Lusardi, Mitchell and Curto, 2010[43]). The PISA 2015 assessment showed that, on average across the participating OECD countries and economies, socio-economically advantaged students score 89 points higher than disadvantaged students, equivalent to more than one proficiency level (OECD, 2017[14]). Large variations in financial literacy related to socio-economic status, intended as a combination of parents' education, parents' occupations, home possessions and educational resources available in the home, mean that families with high socio-economic status are providing students better opportunities to acquire financial literacy skills than socio-economically disadvantaged families.

In order to provide equality of opportunity, it is important to offer financial education to those who would not otherwise have access to it. Schools are well positioned to advance financial literacy among all demographic groups and reduce financial literacy gaps and inequalities (including across generations). Financial literacy performance is strongly correlated with performance in mathematics and reading, suggesting that, whilst not sufficient, a good basic education in core subjects will benefit students when dealing with financial matters (OECD, 2017[14]). Nevertheless, basic mathematics and reading literacy does not provide the specific content knowledge, and students should be helped to improve their financial literacy with more specific financial literacy content. Several countries have started integrating some financial literacy topics into existing subjects, such as mathematics or social sciences. While dedicated financial literacy approaches are relatively new and more evidence on effective approaches would be beneficial, it is important to provide early opportunities for establishing the foundations of financial literacy, as efforts to improve the financial knowledge and skills of adults in the workplace or in other settings can be severely limited by a lack of early exposure to financial education and by a lack of awareness of the benefits of continuing financial education.

Existing empirical evidence shows that young people and adults in both developed and emerging economies who have been exposed to good quality financial education are subsequently more likely than others to plan ahead, save and engage in other responsible financial behaviours (Atkinson et al., 2015[44]; Bruhn et al., 2016[45]; Kaiser and Menkhoff, 2016[46]; Miller et al., 2014[47]; Amagir et al., 2018[48]). Results from a meta-analysis of 126 studies looking at the impact of a variety of financial education interventions on financial literacy show an effect size of 0.26 on average (Kaiser and Menkhoff, 2016[46]). Another systematic literature review of the effectiveness of financial education programmes for children and adolescent shows that school-based financial-education can improve children’s and adolescents’ financial knowledge and attitudes, but studies looking at the impact on actual financial behaviour are scarce (Amagir et al., 2018[48]).

This evidence suggests a possible causal link between financial education and financial literacy levels and indicates that improved levels of financial literacy can lead to improved financial outcomes.

Other research indicates a number of potential benefits of being financially literate. There is evidence that in developed countries those with higher financial literacy are better able to manage their money, participate in the stock market and perform better on their portfolio choice, and that they are more likely to choose mutual funds with lower fees (Clark, Lusardi and Mitchell, 2017[49]; Hastings and Tejeda-Ashton, 2008[50]; van Rooij, Lusardi and Alessie, 2011[51]; Gaudecker, 2015[52]). In emerging economies, financial literacy is shown to be correlated with holding basic financial products like bank accounts and insurance (Grohmann, Kluhs and Menkhoff, 2017[53]; Xu and Zia, 2012[54]); similarly, bank account holding among 15-year-old students is associated with higher levels of financial literacy on average across the OECD countries participating in the 2012 and 2015 PISA exercise (OECD, 2014[1]; 2017[14]). Moreover, adults who have greater financial knowledge are more likely to accumulate higher amounts of wealth (Behrman et al., 2012[55]; van Rooij, Lusardi and Alessie, 2012[56]).

Financial literacy has also been found to be related to debt choices and debt management, with more financially literate individuals opting for less costly and less complex mortgages, and avoiding high interest payments and additional fees (Disney and Gathergood, 2013[57]; Lusardi and Tufano, 2015[58]; Gathergood and Weber, 2017[59]).

In addition to the benefits identified for individuals, widespread financial literacy can be expected to improve economic and financial stability, as well as to support sustainable and inclusive growth (OECD, 2006[60];

EU, 2018[7]). Financially literate consumers can make more informed decisions, shop around for products and demand higher quality services, which can, in turn, encourage competition and innovation in the market. As financially literate people can protect themselves to a greater extent against the negative consequences of income or expenditure shocks, are more likely to take appropriate steps to manage the risks transferred to them, and are less likely to default on credit commitments, they can better face macro level shocks and become more financially resilient. Improving financial literacy among vulnerable populations may especially contribute to reducing wealth inequalities. Financially literate consumers are more likely to have long-term financial attitudes and to understand the implications of personal financial decisions on the society, the economy and the environment.

Box 3.2. OECD activities in relation to financial literacy

In 2002, the OECD initiated a far-reaching financial education project to address governments' emerging concerns about the potential consequences of low levels of financial literacy. This project is serviced by the OECD Committee on Financial Markets and the Insurance and Private Pensions Committee, in coordination with other relevant bodies including the PISA Governing Board and the Education Policy Committee on issues related to schools. The project takes a holistic approach to financial-consumer issues that highlights how, alongside improved financial access, adequate consumer protection and regulatory frameworks, financial education has a complementary role to play in promoting financial well-being.

Recognising the increasingly global nature of financial literacy and education issues, in 2008 the OECD created the International Network on Financial Education (INFE) to benefit from and encompass the experience and expertise of developed and emerging economies. More than 280 public institutions from more than 130 countries are economies are members of the INFE as of 2023. Members meet twice yearly to discuss the latest developments in their country, share their expertise, and collect evidence, as well as to develop analytical and comparative studies, methodologies, good practice, policy instruments and practical guidance on key priority areas.

Important milestones included the endorsement by G20 leaders of the OECD/INFE High-level Principles on National Strategies for Financial Education in 2012 (OECD/INFE, 2012[10]) and the adoption of the Recommendation on Financial Literacy by the OECD Council in 2020 (OECD, 2020[61]).

The 2020 OECD Recommendation advised to “take measures to develop financial literacy from the earliest possible age” (OECD, 2020[61]). Two main reasons underpin the OECD recommendation: the importance of focusing on youth in order to provide them with key life skills before they start to become active financial consumers, and the relative efficiency of providing financial education in schools rather than attempting remedial actions in adulthood.

The OECD/INFE developed a dedicated publication on Financial Education for Youth: The Role of Schools, which was welcomed by G20 leaders in 2013 (OECD, 2014[62]). The publication includes case studies and guidelines on teaching financial literacy in school, which have also been supported by the Ministers of Finance of the Asia-Pacific Economic Cooperation (APEC) in 2012 (APEC, 2012[63]). More case studies on the development of financial education programme for children and young people, in and outside of schools, are included in subsequent publications (OECD, 2019[64]; 2021[65]).

Following a G20 call in 2013, the OECD/INFE developed a Core competencies framework on financial literacy for youth, which describes the financial literacy outcomes that are likely to be important for 15 to 18 year olds and provides a tool for policy makers to develop national learning and assessment frameworks. This was followed by the EU/OECD Financial competence framework for youth and children in the EU, to be published in 2023. Both frameworks build on the lessons learned from developing the PISA 2012 financial literacy assessment framework and analysing the PISA financial literacy data (OECD, 2015[2]; 2020[66]; 2013[30]).

The three volumes collecting the results of the PISA 2012, 2015 and 2018 financial literacy assessments provide not only international evidence on the distribution of financial literacy among 15-year old students with and across countries, but also policy suggestions on how policy makers can improve it (OECD, 2014[1]; 2017[14]; 2020[66]).

The continued need for data

PISA 2012 was the first large-scale international study to assess the financial literacy of young people. Followed by two similar assessments in 2015 and 2018, the PISA financial literacy assessment has regularly provided evidence not only on countries' average levels of financial literacy of their 15-year-old students, but also valuable insights into how financial competencies are distributed along socio-demographic characteristics and about the correlation with mathematics and reading abilities. PISA financial literacy assessments have also provided internationally comparable data on students' experience with money matters, on how they would approach saving and spending decisions, and on their access to basic financial products.

Policy makers, educators and researchers continue to need high-quality data on levels of financial literacy in order to inform financial education strategies and the implementation of financial education programmes in schools. Over 70 countries around the world are developing or implementing national strategies for financial education, following OECD/INFE guidance, and most of them include young people and students as primary target groups (OECD, 2015[11]). As recalled above, more and more countries have started introducing financial literacy content into school curricula at various levels, typically as part of existing subjects. Up-to-date evidence on the financial literacy of students is crucial in the development of these policies.

A robust measure of financial literacy amongst young people provides information at a national level that can indicate whether the current approach to financial education is effective. In particular, it can help to identify issues that need addressing through schools or extra-curricular activities or programmes that will enable young people to be properly and equitably equipped to make financial decisions in adulthood. It can also be used as a baseline from which to measure success and review school and other programmes in future years.

An international study provides additional benefits to policy makers and other stakeholders. Comparing levels of financial literacy across countries makes it possible to see which ones have the highest levels of financial literacy and begin to identify particularly effective national strategies and good practices. It also makes it possible to recognise common challenges and explore the possibility of finding international solutions to the issues faced.

Defining financial literacy

PISA focuses on young people’s ability to use their knowledge and skills to meet real-life challenges, rather than merely on the extent to which they have mastered specific curricular content. PISA conceives of literacy in general as the capacity of students to apply knowledge and skills in key subject areas and to analyse, reason and communicate effectively as they pose, solve and interpret problems in a variety of situations.

The OECD defines financial education as “the process by which financial consumers/investors improve their understanding of financial products, concepts and risks and, through information, instruction and/or objective advice, develop the skills and confidence to become more aware of financial risks and opportunities, to make informed choices, to know where to go for help, and to take other effective actions to improve their financial well-being” (OECD/INFE, 2012[10]).

The 2020 Recommendation on Financial Literacy defines financial literacy as "a combination of awareness, knowledge, skill, attitude and behaviour necessary to make sound financial decisions and ultimately achieve individual financial well-being".

The financial literacy definition created in the context of PISA 2012 is considered to be still relevant and appropriate, and only a minor change is suggested with respect to previous versions of the framework. In practice, the words "motivation and confidence" have been replaced with "attitudes" as a way of taking into account that a broad set of attitudes is related to cognitive aspects of financial literacy and is important for financial behaviour.

The revised definition is as follows:

Financial literacy is knowledge and understanding of financial concepts and risks, as well as the skills and attitudes to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life.

This definition, like other PISA domain definitions, has two parts. The first part refers to the kind of thinking and behaviour that characterises the domain. The second part refers to the purposes for developing the particular literacy.

In the following paragraphs, each part of the definition of financial literacy is considered in turn to help clarify its meaning in relation to the assessment.

Financial literacy…

Literacy is viewed as an expanding set of knowledge, skills and strategies, which individuals build on from a young age and throughout life, rather than as a fixed quantity, a line to be crossed, with illiteracy on one side and literacy on the other. Literacy involves more than the reproduction of accumulated knowledge and it involves a mobilisation of cognitive and practical skills, and other resources such as attitudes, motivation and values. The PISA assessment of financial literacy draws on a range of knowledge and skills associated with the development of the capacity to deal with the financial demands of everyday life and uncertain futures within contemporary society.

Some national and international institutions refer to “financial capability” instead of “financial literacy” in order to put more emphasis on people’s ability to make financial decisions. In most cases the definitions of the two concepts overlap to a large extent, as they both encompass the knowledge, attitudes, skills, and behaviours of consumers. The PISA assessment will continue to refer to financial literacy as its definition is now internationally acknowledged, and for consistency with previous assessments and existing OECD and G20 work.

…is knowledge and understanding of financial concepts and risks…

Financial literacy is thus contingent on some knowledge and understanding of fundamental elements of the financial world, including key financial concepts as well as the purpose and basic features of financial products. Some students already have experience of financial products and commitments through a bank account or a mobile phone contract. A grasp of concepts such as interest, inflation, and value for money are soon going to be, if they are not already, important for their financial well-being.

Adolescents are beginning to acquire financial knowledge and skills, and gain experience of the financial environment that they and their families inhabit (CFPB, 2016[42]; Whitebread and Bingham, 2013[41]). Fifteen-year-old students are likely to have been shopping to buy household goods or personal items; some will have taken part in family discussions about money and whether what is wanted is actually needed or affordable; and a sizeable proportion of them will have already begun to earn and save money; many of them will have access to payment facilities on line or though mobile phones.

Knowledge and understanding of risks that may threaten their financial well-being, including those arising from new types of digital and traditional financial services is also important. At the same time, financially literate students would have an understanding of the purpose of products such as insurance policies and pensions that are intended to mitigate certain risks.

…as well as the skills…

These skills include generic cognitive processes such as accessing information, comparing and contrasting, extrapolating and evaluating – applied in a financial context. They include basic skills in mathematical literacy such as the ability to calculate a percentage, undertake basic mathematical operations or convert from one currency to another, and language skills such as the capacity to read and interpret advertising and basic contractual texts.

…and attitudes…

Financial literacy involves not only the knowledge, understanding and skills to deal with financial issues, but also non-cognitive attributes: the motivation to seek information and advice in order to engage in financial activities, the confidence to approach various types of financial providers and to engage in financial decisions, the ability to focus on the long-term, and the ability to exercise self-control and manage other emotional and psychological factors that influence financial decision making. These attributes are considered as a goal of financial education, as well as being instrumental in building financial knowledge and skills.

…to apply such knowledge and understanding in order to make effective decisions…

PISA focuses on the ability to activate and apply knowledge and understanding in real-life situations rather than the reproduction of knowledge. In assessing financial literacy, this translates into a measure of young people’s ability to transfer and apply what they have learnt about personal finance into effective decision-making. The term “effective decisions” refers to informed and responsible decisions that satisfy a given need.

…across a range of financial contexts…

Effective financial decisions apply to a range of financial contexts that relate to young people’s present daily life and experience, but also to steps they are likely to take in the near future as adults. For example, young people may currently make relatively simple decisions such as how they will use their pocket money or which mobile phone contract they will choose; but they may soon be faced with major decisions about education and work options with long-term financial consequences.

…to improve the financial well-being of individuals and society…

Financial literacy in PISA is primarily conceived of as literacy around personal or household finance, distinguished from economic literacy, which covers concepts such as the theories of demand and supply and market structures. Financial literacy is concerned with the way individuals understand, manage and plan their own and their households’ – which often means their families’ – financial affairs. It is recognised, however, that good financial understanding, management and planning on the part of individuals has some collective impact on the wider society, in contributing to local prosperity as well as national and even global stability, productivity, sustainability and development.

…and to enable participation in economic life.

Like the other PISA literacy definitions, the definition of financial literacy implies the importance of the individual’s role as a thoughtful and engaged member of society. Individuals with a high level of financial literacy are better equipped to make decisions that are of benefit to themselves and their family or community, and also to constructively support and critique the economic world in which they live.

Organising the domain

The representation and organisation of a domain within PISA determines the assessment design and the conceptual structure for the development of cognitive questions (PISA refers to the questions used in the cognitive test as ‘items’). The concept of financial literacy includes many elements, not all of which can be incorporated in an assessment such as PISA. It is therefore necessary to select the most relevant elements across the domain to develop assessment items at various levels of difficulty that are appropriate for 15-year-old students.

A review of approaches and rationales adopted in previous large-scale studies, and particularly in PISA, shows that most specify what they wish to assess in terms of the relevant content, processes and contexts for assessment. Content, processes and contexts can be thought of as three different perspectives on the area to be assessed.

Content comprises the areas of knowledge and understanding that are essential in the area of literacy in question.

Processes describes the mental strategies or approaches that are called upon to negotiate the material.

Contexts refers to the situations in which the domain knowledge, skills and understandings are applied, ranging from the personal to the global.

The steps of identifying and weighting the different categories within each perspective, and then ensuring that the set of tasks in the assessment adequately reflects these categories, are used to ensure the coverage and validity of the assessment. The three perspectives are also helpful in thinking about how achievement is to be reported.

The following section presents a discussion of each of the three perspectives and the framework categories into which they are divided. For each perspective, the framework presents lists of sub-topics and examples of what the items can ask students to show; however, these details should not be interpreted as a checklist of tasks included in any one assessment. Given that only one hour of financial literacy assessment material is being administered in PISA, there is not enough space to cover every detail of each variable.

Content

The content of financial literacy is conceived of as the areas of knowledge and understanding that must be drawn upon in order to perform a particular task. A review of the content of existing financial literacy learning frameworks indicated that there is some consensus on the financial literacy content areas (OECD, 2014[67]; OECD, 2015[2]). The review showed that the content of financial education for young people and in schools was – albeit with cultural differences – relatively similar, and that it was possible to identify a series of topics commonly included in these frameworks. These form the four content areas for PISA financial literacy: *money and transactions, planning and managing finances, risk and reward,* and *financial landscape*. The work undertaken by the OECD/INFE to develop a core competencies framework on financial literacy for youth provides additional guidance on how these content areas map to desired financial literacy outcomes (OECD, 2015[2]).

Money and transactions

This content area includes awareness of the different forms and purposes of money and managing monetary transactions, which may include being aware of digital and foreign currencies, spending or making payments using a variety of available tools including mobile or online ones, using bank cards, cheques, bank accounts. It also covers practices such as taking care of cash and other valuables, calculating value for money, and filing documents and receipts, including those received electronically.

Tasks in this content area can, for example, ask students to show that they:

Are aware of the different forms and purposes of money:

- recognise bank notes and coins;
- understand that money can be exchanged for goods and services;
- understand that money spent on something is not available to be spent on something else;
- recognise that money can be stored in various ways, including at home, in a bank, in a post office or in other financial institutions, in cash or electronically;
- understand that money held in cash may lose value in real terms over time if there is inflation;
- recognise that there are various ways of paying for items purchased, receiving money from other people, and transferring money between people or organisations such as cash, cheques, card payments in person or online, electronic transfers online or via SMS or contactless payments with smartphones, and that new ones continue to be developed;
- understand that money can be borrowed or lent, and the purpose of interest (taking into account that the payment and receipt of interest is forbidden in some religions);
- are aware that other countries may use different currency from their own, and that exchange rates may change over time; and
- are aware of digital currencies.

Are confident and capable at handling and monitoring transactions:

- can use cash, cards and payment methods through computers and mobile phones to purchase items;
- can use cash machines to withdraw cash;
- can check an account balance over the internet or through cash machines;
- can check receipts after making purchases, and can calculate the correct change if the transaction is made in cash;
- can work out which of two consumer items of different sizes would give better value for money, and understand that this may vary depending on the specific needs and circumstances of the consumer;
- can use common tools, such as paper-and-pen, spreadsheets, online platforms or mobile applications to monitor their transactions and support budget calculations; and
- can check transactions listed on a bank statement provided on paper or digitally, and note any irregularities.

In many PISA questions, the unit of currency is the imaginary Zed. PISA questions often refer to situations that take place in the fictional country of Zedland, where the Zed is the unit of currency. This artifice (about which students are informed at the beginning of the testing session) has been introduced to enhance comparability across countries.

Planning and managing finances

Income, expenditure and wealth need planning and managing over both the short term and long term. This content area therefore reflects the process of monitoring, managing, and planning income and expenses, and understanding ways of enhancing wealth and financial well-being. It includes content related to credit use as well as savings and wealth creation.

This content area includes:

Knowledge and ability to monitor and control income and expenses:

- identify various types of income relevant for young people and for adults (e.g. pocket money, allowances, salary, commission, benefits),
- be aware that rules for engaging in gainful employment may be different across young people and adults;
- understand different ways of discussing income (such as hourly wage and gross or net annual income) and that some factors that may affect income (such as different education or career paths);
- draw up a budget to plan regular spending and saving and stay within it; and
- be aware of factors that impact on living standards for any given income, including location, number of dependents and existing commitments.

Knowledge and ability to make use of income and other available resources in the short and long terms to enhance financial well-being:

- understand the difference between needs and wants and the idea of living within one's means;
- understand how to manipulate various elements of a budget, such as thinking about different options for spending money, identifying priorities if income does not meet planned expenses, or finding ways to increase savings, such as reducing expenses or increasing income;
- assess the impact of different spending plans and be able to set spending priorities in the short and long term, also in the context of external spending pressure;
- understand the benefits of a financial plan for future events and plan ahead to pay future expenses: for example, working out how much money needs to be saved each month to make a particular purchase or pay a bill;
- understand that expenditure can be adjusted over time through borrowing or saving;
- understand the reasons why people may use credit, that borrowing money entails a responsibility to repay it, and that the amount to be repaid is usually larger than the amount borrowed due to interest payments (taking into account that the payment and receipt of interest is forbidden in some religions);
- understand the idea of building wealth, the impact of compound interest on savings, and the reasons why some people use investment products;
- understand the benefits of saving for long term goals or anticipated changes in circumstances (such as living independently);
- understand the risks of saving in cash, including the fact that money can be lost, stolen or may lose part of its value in real terms due to inflation; and
- understand how government taxes and benefits impact on personal and household finances.

Risk and reward

Risk and reward is a key area of financial literacy, incorporating the ability to identify ways of balancing and covering risks and managing finances in uncertainty and an understanding of the potential for financial gains or losses across a range of financial contexts. Various types of risk are important in this domain. The first relates to the risk of financial losses that an individual cannot directly predict, and could not realistically cover from personal resources, such as those caused by catastrophic incidents; these are typically insurable risks. The second comes from changes in circumstances that impact on ability to maintain the same standard of living; which may or may not be insurable. The third is the risk inherent in financial products, such as the risk of facing an increase in repayments on a credit agreement with variable interest rates, or the risk of loss or insufficient returns on investment products. This content area therefore includes knowledge of the main risks inherent in certain products, and the behaviours, strategies and types of products that may help people to protect themselves from the consequences of negative outcomes, such as insurance and savings.

This content category includes:

- Identifying those risks that - should the incident occur - are most likely to have a serious negative affect on a particular person, such as:
    - accident or injury,
    - theft of personal property, passwords or data and digital assets,
    - damage or loss of personal property,
    - man-made and/or natural catastrophes.
- Identifying and managing risks and rewards associated with life events or the economy, such as the potential impact of:
    - job loss, birth or adoption of a child, deteriorating health or mobility;
    - fluctuations in interest rates and exchange rates; and
    - other market changes.
- Recognising that certain financial products (including insurance) and processes (such as saving) can be used to manage and offset various risks (depending on different needs and circumstances):
    - understand the benefits of saving for unanticipated changes in circumstances; and
    - knowing how to assess whether certain insurance policies may be of benefit, and the level of cover needed.
- Understanding the risk inherent in certain credit and investment products, such as risk of capital loss, variability of returns, and the implications of variable interest rates on loan repayments.
- Understanding the benefits of contingency planning and diversification to limit the risk to personal capital.
- Applying knowledge of the benefits of contingency planning, diversification and the dangers of default on payment of bills and credit agreements to decisions about:
    - various types of investment, savings and insurance products, where relevant; and
    - various forms of credit, including informal and formal credit, unsecured and secured, rotating and fixed term, and those with fixed or variable interest rates.
- Knowing and being cautious about the risks and rewards associated with substitutes for financial products, such as:
    - saving in cash or in unregulated digital financial instruments (which may include crypto-currencies, depending on national regulation), or buying property, livestock or gold as a store of wealth; and
    - taking credit or borrowing money from informal lenders.
- Knowing that there may be unidentified risks and rewards associated with new financial products (such as mobile payment products and online credit).

Financial landscape

This content area relates to both the character and features of the existing financial world, and the ways in which a wide variety of factors, including technology, innovation, government policy and global sustainable growth measures, can change this landscape over time. It covers awareness of the role of regulation and protection for financial consumers, knowing the rights and responsibilities of consumers in the financial marketplace and within the general financial environment, and the main implications of financial contracts that they may enter into in with parental consent, or alone in the near future. A focus on the financial landscape also takes into account the wide variety of information available on financial matters, from education to advertising. In its broadest sense, *financial landscape* also incorporates an understanding of the consequences of changes in economic conditions and public policies, such as changes in interest rates, inflation, taxation, sustainability and environmental targets, or welfare benefits for individuals, households and society. The implications of financial service provision for the environment, sustainability and inclusion are also relevant within this content area.

Tasks associated with this content area include:

- Awareness of the role of regulation and consumer protection
- Knowledge of rights and responsibilities, and the ability to apply it to:
    - understand that buyers and sellers have rights, such as being able to apply for redress;
    - understand that buyers and sellers have responsibilities, such as:
        - consumers/investors giving accurate information when applying for financial products;
        - providers disclosing all material facts; and
        - consumers/investors being aware of the implications of one of the parties not doing so.
    - recognise the financial implications of contracts;
    - recognise the importance of the legal documentation provided when purchasing financial products or services and the importance of understanding the content.
- Knowledge and understanding of the financial environment, including:
    - Understanding that different people and organisations may have incentives to provide certain financial information, products or services;
    - Being able to identify trusted sources of financial information and advice, and to distinguish marketing and ads from genuine and official information and educational messages;
    - Being alert to ‘fake news’ in the financial domain or with financial implications;
    - identifying which providers are trustworthy, and which products and services are protected through regulation or consumer protection laws;
    - identifying whom to ask for advice when choosing financial products, understanding that financial advice may be biased, and knowing where to go for help or guidance in relation to financial matters; and
- Awareness of the financial risks and implications of sharing personal financial data, awareness that personal data may be used to create a person's digital profile which can be used by companies to offer products and services based on personal factors, and awareness of existing financial crimes such as identity theft and data theft;
- Applying an understanding of the financial risks of a lack of data protection to:
    - take appropriate precautions to protect personal data and avoid scams,
    - conduct online transactions safely,
    - know rights and responsibilities under the applicable regulation, including in the event of being a victim.
- Knowledge and understanding of the (short- and long-term) impact of their own financial decisions on themselves, on others, and on the environment:
    - understand that individuals have choices in spending, saving and investing and each action can have consequences for the individual, for society and possibly for the environment; and
    - recognise how personal financial habits, actions and decisions impact at an individual, community, national and international level
    - understand the financial implications on society of ethics, sustainability and integrity and related behaviours (including for instance donations to non-profits/charities, green investments, corruption).
- Knowledge of the influence of economic and external factors:

- o aware of the economic climate and understand the impact of policy changes such as reforms related to the funding of post-school training or compulsory savings for retirement;
- o understand how the ability to build wealth or access credit depends on economic factors such as interest rates, inflation and credit scores; and
- o understand that a range of external factors, such as advertising and pressure from family, friends and society, can affect individuals' financial choices and outcomes.

Processes

The process categories relate to the cognitive processes that students apply to respond to the assessment. They are used to describe students’ ability to recognise and apply concepts relevant to the domain, and to understand, analyse, reason about, evaluate and suggest solutions. In PISA financial literacy, four process categories have been defined: *identify financial information, analyse financial information and situations, evaluate financial issues* and *apply financial knowledge and understanding*. While the verbs used here bear some resemblance to those in Bloom’s taxonomy of educational objectives (Bloom, 1956), an important distinction is that the processes in the financial literacy construct are not intended as a hierarchy of skills. They are, instead, parallel essential cognitive approaches, all of which are part of the financially literate individual’s repertoire. The order in which the processes are presented here relates to a typical sequence of thought processes and actions, rather than to an order of difficulty or challenge. At the same time, it is recognised that financial thinking, decisions and actions are most often dependent on a recursive and interactive blend of the processes described in this section. For the purposes of the assessment, each task is identified with the process that is judged most central to its completion.

Identify financial information

This process is engaged when the individual searches and accesses sources of financial information, and identifies or recognises its relevance. In PISA the information is in the form of texts such as contracts, advertisements, charts, tables, forms and instructions displayed on screen. A typical task might ask students to identify the features of a purchase invoice, or recognise the balance on a bank statement. A more difficult task might involve searching through a contract that uses complex legal language to locate information that explains the consequences of defaulting on loan repayments. This process category is also reflected in tasks that involve recognising financial terminology, such as identifying “inflation” as the term used to describe increasing prices over time.

Analyse financial information and situations

This process focuses on analysing financial information to recognise relationships in financial contexts, like recognising how loan repayments and interest are affected by the loan period, or recognising which factors affect insurance premiums. It also involves identifying the underlying assumptions or implications of an issue in a financial context, extrapolating from information that is provided, and recognising something that is not explicit, such as comparing the terms offered by different mobile phone contracts, or working out whether an advertisement for a loan is likely to include unstated conditions. In order to do this, the process category requires the use of a wide range of cognitive activities in financial contexts, including interpreting, comparing and contrasting, and synthesising.

Evaluate financial issues

In this process the focus is on recognising or constructing financial justifications and explanations, drawing on financial knowledge and understanding applied in specified contexts, such as explaining advantages and disadvantages of certain financial decisions, or explaining why a certain financial decision may be good or bad for someone given their personal situation. It involves such cognitive activities as explaining, reasoning, assessing and generalising. Critical thinking is brought into play in this process, when students must draw on knowledge, logic and plausible reasoning to make sense of and form a view about a finance-related problem, such as understanding the incentives that different people or institutions may have when they provide financial information or products. The information that is required to deal with such a problem may be partly provided in the stimulus of the task, but students will need to connect such information with their own prior financial knowledge and understandings. In the PISA context, any information that is required to understand the problem is intended to be within the expected range of experiences of a 15-year-old – either direct experiences or those that can be readily imagined and understood. For example, it is assumed that 15-year-olds are likely to be able identify with the experience of wanting something that is not essential (such as a music player or games console). A task based on this scenario could ask about the factors that might be considered in deciding on the relative financial merits of making a purchase or deferring it, given specified financial circumstances.

Apply financial knowledge and understanding

This process focuses on taking effective action in a financial setting by using knowledge of financial concepts and products and applying them in across a variety of financial contexts. This process is reflected in tasks that involve solving problems, including performing simple calculations and taking into account multiple conditions. An example of this kind of task is calculating the interest on a loan over two years. This process is also reflected in tasks that require recognition of the relevance of prior knowledge in a specific context. For example, a task might require the student to work out whether purchasing power will decline or increase over time when prices are changing at a given rate. In this case, knowledge about inflation needs to be applied.

Contexts

In building a framework, and developing and selecting assessment items based on this framework, attention is given to the breadth of contexts in which the domain literacy is exercised. Decisions about financial issues are often dependent on the contexts or situations in which they are presented. By situating tasks in a variety of contexts the assessment offers the possibility of connecting with the broadest possible range of individual interests across a variety of situations in which individuals need to function in the 21st century.

Certain situations will be more familiar to 15-year-olds than others. In PISA, assessment tasks are framed in situations of general life, which may include but are not confined to school contexts. The focus may be on the individual, family or peer group, on the wider community, or even more widely on a global scale.

The contexts identified for the PISA financial literacy assessment are, then, *education and work, home and family, individual* and *societal*.

Education and work

The context of *education and work* is of great importance to young people. Virtually all 15-year-olds will be starting to think about financial matters related to both education and work, whether they are spending existing earnings, considering future education options or planning their working life.

The educational context is obviously relevant to PISA students, since they are by definition a sample of the school-based population; indeed, many of them will continue in education or training for some time. However, many 15-year-old students are also already engaged in some form of paid work outside school hours making the work context equally valid. Furthermore, many will move from education into some form of employment, including self-employment, before reaching their twenties.

Typical tasks within this context could include understanding payslips, planning to save for tertiary education, investigating the benefits and risks of taking out a student loan, and participating in workplace savings schemes.

Home and family

*Home and famil*y includes financial issues relating to the costs involved in running a household. Family is the most likely household circumstance for 15-year-olds; however, this category also encompasses households that are not based on family relationships, such as the kind of shared accommodation that young people often use shortly after leaving the family home. Tasks within this context may include buying household items or family groceries, keeping records of family spending and making plans for family events. Decisions about budgeting and prioritising spending may also be framed within this context.

Individual

The context of the *individual* is important within personal finance since there are many decisions that a person takes entirely for personal benefit or gratification, and many risks and responsibilities that must be borne by individuals. These decisions span essential personal needs, as well as leisure and recreation. They include choosing personal products and services such as clothing, toiletries or haircuts, or buying consumer goods such as electronic or sports equipment, as well as commitments such as season tickets or a gym membership. They also cover the process of making personal decisions and the importance of ensuring individual financial security such as keeping personal information safe and being cautious about unfamiliar products.

Although the decisions made by an individual – especially at 15 – may be influenced by the family and society (and may impact society), when it comes to opening a bank account, buying shares or getting a loan it is typically the individual who has the legal responsibility and ownership. This context includes also financial behaviours that are typically carried out at the individual level, such as making purchases online or through mobile applications, even though they may be influenced by or have an impact on others such as parents and friends. The context *individual* therefore includes contractual issues around events such as opening a bank account or holding a payment card, purchasing consumer goods and paying for recreational activities through a variety of traditional and digital channels, and dealing with relevant financial services that are often associated with larger consumption items, such as credit and insurance.

Societal

The environment young people are living in is characterised by change, complexity and interdependence. Globalisation is creating new forms of interdependence where actions are subject to economic influences and consequences that stretch well beyond the individual and the local community. Digitalisation is making the pace and the effects of such global interdependence faster and more widespread. Financial investment decisions are increasingly incorporating environmental, social and governance considerations with the aim of promoting sustainable economic growth and increasing the awareness of the risks which may have an impact on the sustainability of the financial system. While the core of the financial literacy domain is focused on personal finances, the societal context recognises that individual financial well-being is not only about personal or family money management and cannot be entirely separated from the rest of society.

As recalled in the PISA definition, financial literacy should allow young people, among other goals, to "*improve the financial well-being of individuals and society*". Tasks in this category are related to situations where personal financial well-being affects and is affected by the local community, the nation and even global activities. Examples may include being informed about consumer rights and responsibilities, understanding the purpose of taxes and local government charges, being aware of business commercial interests, and understanding the financial implications of personal actions on the society, economy and environment at large.

Non-cognitive factors

PISA conceives of financial attitudes and behaviour as aspects of financial literacy in their own right. Attitudes and behaviour are also of interest in terms of their interactions with the cognitive elements of financial literacy. The non-cognitive data collected through the PISA questionnaires offer the possibility to explore the relationship between non-cognitive factors that can be related to (cognitive) financial literacy (keeping in mind that the establishment of causal links between cognitive aspects and students' attitudes, behaviours and outcomes is not possible with PISA data). Information collected about the financial attitudes and behaviour of 15-year-olds can also potentially constitute useful baseline data for any longitudinal investigation of the financial literacy of adults, including their financial behaviours. The framework identifies four broad groups of non-cognitive factors that are relevant for young people's financial literacy. Non-cognitive factors include a combination of:

- Contextual factors that may be related to students' opportunities to improve their financial literacy, such as *access to information and education;*
- Students' behaviours and opportunities to learn by doing in terms of *access to and use of money and financial products;*
- *Financial attitudes* that are expected to be associated with cognitive aspects of financial literacy;
- Self-reported *financial behaviour* that can be considered as an outcome of the cognitive aspects of financial literacy.

Access to information and education

There are various sources of financial information and education that may be available to students, including informal discussion with parents or other family members, friends, formal school education, as well as information from the media and the financial sector (even though not all this information is appropriate to 15-year-old people, relevant to them and tailored to their needs). The literature in this area often refers to the process of 'financial socialisation', which can be seen as the process of acquiring and developing the values, attitudes, standards, norms, knowledge and behaviours that contribute to people's independent financial viability and well-being (Danes, 1994[68]). Parents have a major role in the financial socialisation of children but, as discussed above, they may not have experienced all financial contexts and decisions that their children face (Gudmunson and Danes, 2011[69]; Otto, 2013[70]). Copying and discussing financial behaviours with friends is another important source of socialisation, but this may also vary in terms of quality and reliability, with research from the UK indicating that money is rarely talked about honestly (Money Advice Service, 2014[71]).

The amount and quality of formal education and training about money and personal finance received by students varies within and across countries (OECD, 2014[67]). Data about students' access to financial information and education can be collected through the student questionnaire and/or the questionnaire for school principals. In the student questionnaire, students can be asked about the typical sources of information that they access in order to analyse the extent to which each source is correlated with financial literacy. This is intended to provide a description of students' main sources of financial socialisation, rather than assessing whether they understand the importance of using appropriate sources of information or advice, which is covered in the cognitive assessment. Students can also be asked about the types of tasks that they face and the financial concepts they are exposed to during curricular classes, such as whether they have heard of or learnt about specific financial concepts during school lessons, whether they have encountered some types of tasks about money matters at school, and to what extent these topics are covered in their school textbooks. Students could also be asked about their exposure to opportunities to learn about financial issues in extra-curricular educational contexts, to innovative ways of learning financial education, such as e-learning platforms, mobile apps and other digital tools, and to delivery channels developed using behavioural insights.

In addition, the school questionnaire can ask principals about the availability and quality of financial education in their schools, the availability of appropriate teaching material and professional development opportunities. Evidence about the extent to which there is a link between levels of financial literacy and financial education inside and outside schools is likely to be particularly useful in shaping education programmes for improving financial literacy.

Access to and use of money and financial products

The results of the 2012, 2015 and 2018 PISA financial literacy exercise showed that in some countries students with a bank account scored higher in financial literacy than students with similar socio-economic status who did not hold a bank account (OECD, 2014[1]; 2017[14]; 2020[66]). Whilst this does not indicate a causal relationship, it is plausible to assume that real-life experiences of financial products may influence young people’s financial literacy and vice versa.

Personal experience may come, for example, from using financial products such as payment cards, from dealing with the banking system, whether in person, on line or via a mobile phone, or from occasional working activities outside of school hours. Having personal experience of dealing with financial matters might be expected to be positively associated to financial literacy performance on the cognitive assessment; however, many factors may intervene in this relationship. The relationship between accessing financial services and financial literacy may go both ways. The relationship between receiving pocket money or money from some type of working activity may be mediated by the role of parents, and the time and frequency that is associated with these experiences.

It is therefore important to supplement cognitive data with information on whether students have access to and use financial products and/ or money, through which channels, to what extent such use is discussed with parents, the quality of these discussions, and possibly some information on the time dedicated to certain working activities. Future assessments should ensure that questions about access and use of financial products reflect the range of products and services to which students are exposed, including especially digital services and tools.

Financial attitudes

The PISA definition of financial literacy highlights the important role of attitudes. Individual preferences can determine financial behaviour and impact on the ways in which financial knowledge is used. PISA 2012 showed that students’ perseverance and openness to problem solving were strongly associated to their financial literacy scores (OECD, 2014[1]). PISA 2015 showed a positive association between students' financial literacy and their motivation to achieve (OECD, 2017[14]). In addition, other attitudes can be relevant to young people's financial behaviour and can interact with the cognitive aspects of their financial literacy. The following list indicates attitudes that could be explored in future financial literacy assessments (not necessarily all in the same cycle):

Long-term orientation is a key factor related to individual economic and financial decision-making (Deaton, 1992[72]). Students' preferences for current consumption may influence their financial decisions and their propensity to learn how to make plans for their own financial security (Golsteyn, Grönqvist and Lindahl, 2014[73]; Meier and Sprenger, 2013[74]; Lee and Mortimer, 2009[75]). In PISA 2012, an attempt was made to include some questions about time preferences in the student questionnaire, but the questions were dropped after the field trial. Future assessments could try to find better ways of asking students about their long-term orientation, such as considering the use of the future time perspective (FTP) construct (Kooij et al., 2018[76]; Andre et al., 2018[77]).

Confidence in one’s own ability to make a financial decision, using a financial product or approaching a financial provider may be a key driver in explaining who will work through complex financial problems or make choices across several possible products. At the same time, however, confidence may turn into overconfidence, leading to a tendency to make mistakes and overly risky decisions (Moore and Healy, 2008[78]). The PISA 2018 assessment asks students about their confidence in dealing with various financial matters, from understanding a bank statement to using digital devices to make payments. Future assessments could investigate confidence and overconfidence further.

Many young peoples' attitudes towards money can be summarised as ‘spend today, worry tomorrow’ (Money Advice Service, 2014[71]). Students who are unable to control urges for immediate gratification can be more prone to impulse spending, may find it difficult to resist spending pressure from peers, family, society and advertisements, and may be less able to stick to commitments (such as repaying a student loan) and to saving plans (Mansfield, Pinto and Parente, 2003[79]). Moreover, self-control during childhood predicts important adult outcomes, including socio-economic status and financial difficulties (Moffitt et al., 2011[80]). Self-control in a financial context has not been investigated so far in PISA financial literacy assessments.

Adolescents are typically more risk tolerant than adults (Braams et al., 2015[81]). A high willingness to take risks among young people may be related with key decisions that they may face soon after completing compulsory education, such as taking a student loan, owning a car or buying insurance. The PISA 2012 field trial included some questions about risk aversion but these were not retained for the main surveys. Future assessments could try to find better ways of asking students about their attitudes towards risk.

Young people are generally not very interested in financial topics (Chen and Volpe, 2002[82]) and a lack of interest can be related to a lack of motivation and confidence in engaging with everyday financial issues. Many young people also feel that talking about money is "taboo" (Money Advice Service, 2017[83]). Feeling uncomfortable and embarrassed about discussing money or financial matters may lead to a lack of willingness in engaging with everyday financial issues and in asking for advice to trusted adults in difficult situations. PISA financial literacy assessments so far have not investigated the extent to which students are interested in financial issues, consider them uninteresting and/ or feel uncomfortable in talking about money.

Financial behaviour

While items on the cognitive assessment test students’ ability to make particular financial decisions in real-life scenarios, it is also useful to have some measure of what their actual (self-reported) behaviour is: that is, how students behave in practice. While PISA data do not indicate causal relationships, the non-cognitive elements of financial behaviour may nevertheless be considered as outcomes of students’ financial knowledge and skills.

In the 2012 and 2015 assessments, PISA looked at students' self-reported behaviour in hypothetical spending and saving situations, thus providing the opportunity to look at the relationship between 15-year-olds’ spending and saving behaviour and their results on the cognitive financial literacy assessment. However, many students did not reply to these questions, perhaps because they found them too sensitive, and reporting the results was made difficult by high rates of missing values. The PISA 2018 assessment further explores various aspects of how students make spending decisions, such as whether they compare prices, check change or buy items that cost more that they intended to spend.

Future assessments should continue to investigate students' spending and saving behaviour, for instance by looking at what items do young people save on, whether they compare products and shop around, the role of digital financial services and digital tools in general in affecting their spending decisions, and the possible mediating role of parents in these decisions. Other behaviours that could be investigated include keeping track of expenses and budgeting. Some studies have looked at how participation in financial education initiatives in school affected students’ outcomes, focusing mostly on saving, spending and credit behaviour (Frisancho, 2018[84]; Bruhn et al., 2016[45]; Urban et al., 2018[85]).

Assessing financial literacy

The structure of the assessment

In 2012, the PISA financial literacy assessment was developed as a one-hour paper-and-pen exercise, to be completed alongside one hour of material from other cognitive domains. The financial literacy assessment was made of 40 items divided into two clusters, chosen from 75 initial tasks administered in the field trial. Students sitting the financial literacy test constituted a separate sample with respect to students taking the core PISA assessment; students who sat the financial literacy test were also tested in mathematics and reading.

In 2015, items were transferred to a computer-based delivery platform, and additional items were developed for this form of delivery in order to replace items that had been released in the report of the 2012 results. The 2015 financial literacy was developed as a one-hour exercise, comprising 43 items divided into two clusters. Students sitting the financial literacy test were a subsample of those taking the core PISA assessment; as such they also sat the standard PISA test of science, mathematics and reading.

The 2018 assessment incorporates 14 new interactive tasks. For instance, some interactive items require the student to actively seek more information by clicking links, rather than relying solely on the information presented on the first screen. Others include graphs that can be manipulated to see a variety of potential outcomes. Such items allow the student to test different scenarios and explain why certain outcomes occur, while at the same time eliminating the need to make calculations and allowing students to focus on financial decisions rather than on numerical calculations. Overall, the PISA 2018 financial literacy assessment consists of 43 items for a total of a one-hour financial literacy exercise. The sample design replicates the one used in the 2012 assessment (separate sample of students sitting the financial literacy, mathematics and reading tests).

The 2022 assessment comprises a mix of existing items to measure changes in performance over time and new interactive items developed to reflect the revised framework. The design of the 2022 financial literacy assessment is similar to the one in 2018. The financial literacy cognitive assessment was administered to a separate sample of PISA-eligible students. Students taking the financial literacy assessment sat a 60-minutes test of financial literacy and a 60-minutes test of either mathematics or reading.

As with other PISA assessment domains, computer-based financial literacy items are grouped in units comprising one or more items based around a common stimulus. The selection includes financially-focused stimulus material in diverse formats, including prose, diagrams, tables, charts and illustrations. All financial literacy assessments comprise a broad sample of items covering a range of difficulty that enable the strengths and weaknesses of students and key subgroups to be measured and described.

Response formats and coding

Some PISA items require short descriptive responses; others require more direct responses of one or two sentences or a calculation, whilst some can be answered by checking a box. Decisions about the form in which the data are collected – the response formats of the items – are based on what is considered appropriate given the kind of evidence that is being collected, and also on technical and pragmatic considerations. In the financial literacy assessment as in other PISA assessments, two broad types of items are used: constructed-response items and selected-response items.

Constructed-response items require students to generate their own answers. The format of the answer may be a single word or figure, or may be longer: a few sentences or a worked calculation. Constructed-response items that require a more extended answer are ideal for collecting information about students' capacity to explain decisions or demonstrate a process of analysis.

The second broad type of item in terms of format and coding, is selected response. This kind of item requires students to choose one or more alternatives from a given set of options. The most common type in this category is the simple multiple-choice item, which requires the selection of one from a set of (usually) four options. A second type of selected-response item is complex multiple choice, in which students respond to a series of “Yes/No” or “True/False”-type questions. Selected-response items are typically regarded as most suitable for assessing items associated with identifying and recognising information, but they are also a useful way of measuring students’ understanding of higher-order concepts that they themselves may not easily be able to express.

Although particular item formats lend themselves to specific types of questions, care needs to be taken that the format of the item does not affect the interpretation of the results. Research suggests that different groups (for example, boys and girls, and students in different countries) respond differentially to the various item formats. Several research studies on response format effects based on PISA data suggest that there are strong arguments for retaining a mixture of multiple-choice and constructed-response items (Grisay and Monseur, 2007[86]; Lafontaine and Monseur, 2006[87]). The PISA financial literacy option includes items in a variety of formats to minimise the possibility that the item format influences student performance.

When considering the distribution of item formats, it is important to weigh resources and equity considerations discussed in the preceding paragraphs. Selected-response items have predefined correct answers that can be computer-coded, therefore demanding fewer resources. While some of the constructed-response items are automatically coded by computer, some elicited a wider variety of responses that cannot be categorised in advance, thus requiring human coding from expert judges. The proportions of constructed- and selected-response items are determined taking account of all these considerations.

Most items are coded dichotomously (full credit or no credit), but where appropriate an item’s coding scheme allows for partial credit. Partial credit makes possible more nuanced scoring of items. Some answers, even though incomplete, are better than others. If incomplete answers for a particular question indicate a higher level of financial literacy than inaccurate or incorrect answers, a scoring scheme has been devised that allows partial credit for that question. Such “partial credit” items yield more than one score point.

Distribution of score points

This section outlines the distribution of score points across the categories of the three main framework characteristics discussed previously. The term “score points” is used in preference to “items”, as some partial credit items are included. The distributions are expressed in terms of ranges, indicating the approximate weighting of the various categories. The distribution contains a mix of original items, developed for the 2012 assessment, and those items developed for subsequent assessments. In particular, care is taken to ensure that interactive items are included across different elements of the assessment.

While each PISA financial literacy item is categorised according to a single content, a single process and a single context category it is recognised that, since PISA aims to reflect real-life situations and problems, often elements of more than one category are present in a task. In such cases, the item is identified with the category judged most integral to responding successfully to the task.

Table 3.1 presents the target distribution of score points according to financial literacy content areas, processes and contexts. It includes the distribution of score points used in the 2012, 2015 and 2018 assessments, and some suggested changes in order to reflect the change in the financial landscape and the financial risk shift towards individuals described in the introduction:

Give slightly more weight to the "risk and reward" and "financial landscape" content areas and slightly less weight to “money and transactions”, while not reducing too much the weight of “planning and managing finances” and

Give slightly less weight to the process "apply financial knowledge and understanding". Applying knowledge and understanding is at the core of the whole financial literacy assessment and it inspires all test items. Nevertheless, in practice, many items under the process category “Apply financial knowledge and understanding” asked students to perform very basic mathematics calculations in a financial context, but with little financial reasoning required (such as calculating an amount of money using an exchange rate or estimating the amount of change from a transaction). This change would reduce the emphasis on numerical skills in cognitive financial literacy tasks, and reduce the overlap between the financial literacy and the mathematics assessments.

In implementing any changes in the actual distribution of items in future assessments, care will be taken to ensure the possibility to compare results with previous assessments.

Table 3.1. Approximate target distribution of score points in financial literacy

Distribution of score points by content areas, processes and context; original distribution and suggested changes

		Original distribution of score points (in the 2012, 2015 and 2018 assessments)	New suggested distribution of score points (suggested changes are highlighted in italics)
Content	Money and transactions	30-40%	*25-35%*
	Planning and managing finances	25-35%	*20-30%*
	Risk and reward	15-25%	*20-30%*
	Financial landscape	10-20%	*15-25%*
Process	Identify financial information	15-25%	15-25%
	Analyse financial information and situations	15-25%	*25-35%*
	Evaluate financial issues	25-35%	25-35%
	Apply financial knowledge and understanding	25-35%	*15-25%*
Contexts	Education and work	10-20%	10-20%
	Home and family	30-40%	30-40%
	Individual	35-45%	35-45%
	Societal	5-15%	5-15%

The interaction of financial literacy with knowledge and skills in other domains

In order to perform well in the financial literacy test, students need to have at least some basic levels of mathematical and reading literacy. They also need some transversal skills that are relevant for young people and adults in the 21st century, such as problem solving skills and critical thinking.

A certain level of numeracy (or mathematical literacy) is regarded as a necessary condition of financial literacy, as some financial decisions may require people to perform some basic calculation, such as percentages. Houston (2010[88]) argues that “if an individual struggles with arithmetic skills, this will certainly impact his/her financial literacy. However, available tools (e.g. calculators) can compensate for these deficiencies; thus, information directly related to successfully navigating personal finances is a more appropriate focus than numeracy skills for a financial literacy measure”. Mathematically-related proficiencies such as number sense, familiarity with multiple representations of numbers, and skills in mental calculation, estimation, and the assessment of reasonableness of results are intrinsic to some aspects of financial literacy.

On the other hand, there are large areas where the content of mathematical literacy and financial literacy do not intersect. As defined in the PISA 2022 mathematical literacy framework, mathematical literacy incorporates four content areas: *change and relationships, space and shape, quantity* and *uncertainty*. Of these, only *quantity* directly intersects with the content of the PISA financial literacy assessment. Unlike the mathematical literacy content area *uncertainty*, which requires students to apply probability measures and statistics, in the PISA assessment the financial literacy content area *risk and reward* requires an understanding of the features of a particular situation or product that indicate that there will be a risk of losing money and (sometimes) a possibility of gains. In the financial literacy assessment, the quantity-related proficiencies listed previously are applied to problems requiring more financial knowledge than can be expected in the mathematical literacy assessment. Similarly, knowledge about financial matters and capability in applying such knowledge and reasoning in financial contexts (in the absence of any specifically mathematical content) characterise much of all four content areas of financial literacy: *money and transactions, planning and managing finances, risk and reward* and *financial landscape*. Figure 3.1 represents the relationship between the content of mathematical literacy and financial literacy in PISA.

Operationally, there are few items populating the portion of the diagram where the two circles intersect. In the financial literacy assessment, the nature of the mathematical literacy expected is basic arithmetic: the four operations (addition, subtraction, multiplication and division) with whole numbers, decimals and common percentages. Such arithmetic occurs as an intrinsic part of the financial literacy context and enables financial literacy knowledge to be applied and demonstrated. Use of financial formulae (requiring capability with algebra) is not considered appropriate. Dependence on calculation is minimised in the assessment; tasks are framed in such a way as to avoid the need for substantial or repetitive calculation. The calculators used by students in their classrooms and on the PISA mathematics assessment will also be available in the financial literacy assessment, but success in the items will not depend on calculator use. Moreover, the suggested change in the target distribution of score points (Table 3.1) goes in the direction of giving less emphasis to the application of basic arithmetic skills in financial contexts by slightly reducing the weight of the process category "Apply financial knowledge and understanding", in order to leave more room for assessing non-numerical financial skills.

A similar reasoning holds for reading skills. Financially literate students should have some basic reading proficiency, to be able to read financial documents and understand financial terms appropriate to the situations they may encounter. To minimise the level of reading literacy required in the PISA financial literacy test, stimulus material and task statements are generally designed to be as clear, simple and brief as possible. While highly technical terminology relating to financial matters is avoided, in some cases, however, stimulus may deliberately present complex or somewhat technical language, as the capacity to read and interpret the language of financial documents or pseudo financial documents is regarded as part of financial literacy.

In practice, the results of the 2012, 2015 and 2018 PISA financial literacy assessments gave a more precise measure of students' performance in financial literacy in comparison with reading and mathematics performance. The results indicated that in 2015 around 38% of the financial literacy score reflected factors that are uniquely captured by the financial literacy assessment, while the remaining 62% of the financial literacy score reflected skills measured in the mathematics and/or reading assessments (OECD, 2017[14]). The association between financial literacy and other domains indicates that, in general, students who perform at higher levels in mathematics and/or reading also perform well in financial literacy. There were, however, wide variations in financial literacy performance for any given level of performance in mathematics and reading, meaning that the skills measured by the financial literacy assessment went beyond or fell short of the ability to use the knowledge that students acquired from subjects taught in compulsory education (OECD, 2014[1]; 2017[14]; 2020[66]).

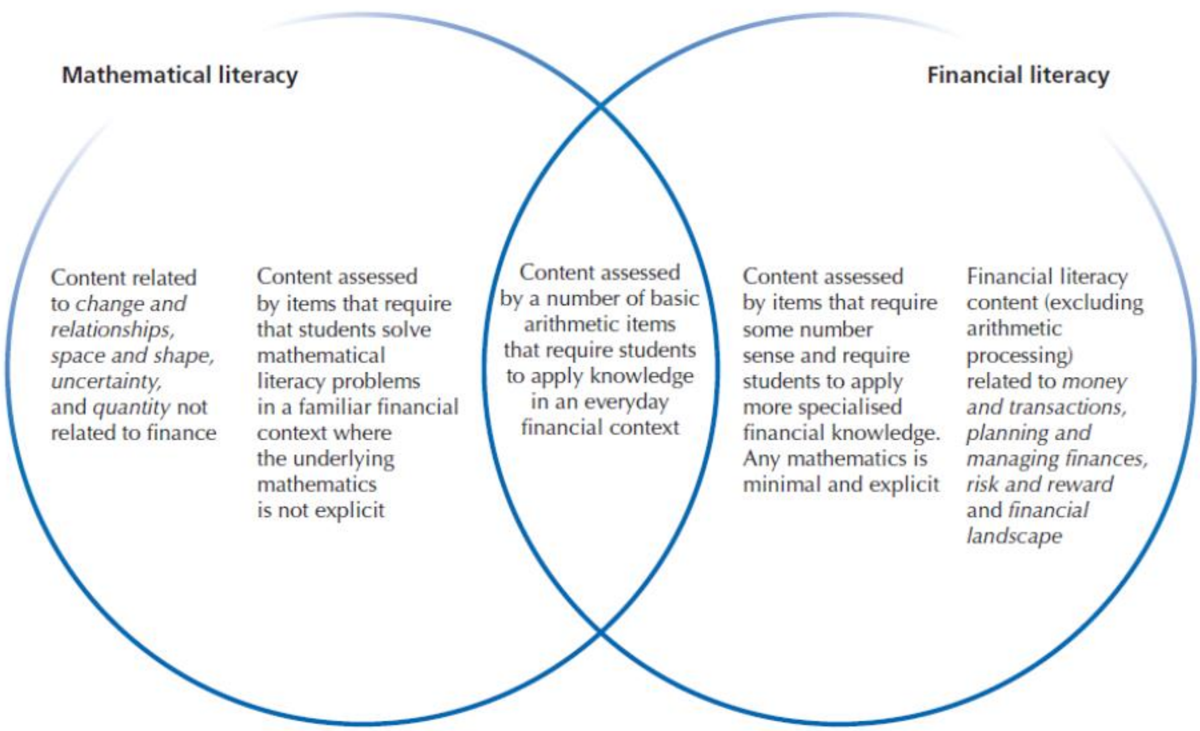
In addition to basic mathematical and reading literacy, a number of other skills are relevant to financial literacy, including problem solving, critical thinking, reflection and anticipation (OECD, 2018[89]). Many of the PISA financial literacy tasks require students to understand and resolve real-life problem situations where the method of solution is not immediately obvious and where some information or conditions are not immediately evident, such as working out an insurance pay-out given certain conditions of the insurance policy.

The PISA financial literacy assessments also requires students to apply their critical thinking to financial situations, such as being able to distinguish between biased and reliable sources of financial information, to choose among a variety of products of providers, and to understand that certain financial decisions may have different consequences on different people depending on their circumstances. Analytical and critical thinking are important to foresee what may be needed in the future and how todays' actions may have consequences in the future.

Being financially literate also requires having a sense of responsibility for one's financial decisions and reflecting upon one's actions and their consequences for personal and societal well-being. This is closely connected to other important 21st century skills such as a sense of ethics, integrity and social responsibility.

Future PISA assessments may build on synergies with other cognitive assessments, such as in the areas of problem solving and critical thinking, to investigate any relations with financial literacy.

Figure 3.1. Relationship between the content of financial literacy and mathematical literacy in PISA



Reporting financial literacy

Financial literacy scale

The financial literacy cognitive data is scaled in a similar way to the other PISA data. The scale summarises both the proficiency of a student in terms of his or her ability and the complexity of an item in terms of its difficulty. The mapping of students and items on one scale represents the idea that students are more likely to be able to successfully complete tasks mapped at the same level on the scale (or lower), and less likely to be able to successfully complete tasks mapped at a higher level on the scale.

Following PISA practice, the scale is constructed as having a mean of 500 and a standard deviation of 100 among participating OECD countries. A comprehensive description of the modelling technique used for scaling can be found in the *PISA Technical Reports* (OECD, 2014[62]; 2017[90]; 2018[91]).

Proficiency levels

In the PISA 2012 assessment, the scale was divided into five proficiency levels, according to a set of statistical principles, and then descriptions were generated based on the tasks located within each level, to encapsulate the kinds of skills and knowledge needed to successfully complete those tasks.

By calibrating the difficulty of each item, it is possible to locate the degree of financial literacy that the item represents. By showing the proficiency of each student on the same scale, it is possible to describe the degree of financial literacy that the student possesses. The described proficiency scale helps in interpreting what students' financial literacy scores mean in substantive terms.

Table 3.2 reports a description of the five proficiency levels. These levels are as they were defined for PISA 2012. New items may help to refine the descriptions of existing levels of performance and may potentially provide sufficient information to describe more levels, above or below those established in PISA 2012.

Table 3.2. Summary description of the financial literacy five proficiency levels

Level	Score range	Percentage of students able to perform tasks at each level (OECD average-10 – PISA 2015)	What student can typically do
1	326 to less than 400 points	21.1%	Students can identify common financial products and terms and interpret information relating to basic financial concepts. They can recognise the difference between needs and wants and can make simple decisions on everyday spending. They can recognise the purpose of everyday financial documents such as an invoice and apply single and basic numerical operations (addition, subtraction or multiplication) in financial contexts that they are likely to have experienced personally.
2 Baseline	400 to less than 475 points	22.6%	Students begin to apply their knowledge of common financial products and commonly used financial terms and concepts. They can use given information to make financial decisions in contexts that are immediately relevant to them. They can recognise the value of a simple budget and can interpret prominent features of everyday financial documents. They can apply single basic numerical operations, including division, to answer financial questions. They show an understanding of the relationships between different financial elements, such as the amount of use and the costs incurred.
3	475 to less than 550 points	26.0%	Students can apply their understanding of commonly used financial concepts, terms and products to situations that are relevant to them. They begin to consider the consequences of financial decisions and they can make simple financial plans in familiar contexts. They can make straightforward interpretations of a range of financial documents and can apply a range of basic numerical operations, including calculating percentages. They can choose the numerical operations needed to solve routine problems in relatively common financial literacy contexts, such as budget calculations.
4	550 to less than 625 points	19.6%	Students can apply their understanding of less common financial concepts and terms to contexts that will be relevant to them as they move towards adulthood, such as bank account management and compound interest in saving products. They can interpret and evaluate a range of detailed financial documents, such as bank statements, and explain the functions of less commonly used financial products. They can make financial decisions taking into account longer-term consequences, such as understanding the overall cost implication of paying back a loan over a longer period, and they can solve routine problems in less common financial contexts.
5	Equal to or higher than 625 points	10.7%	Students can apply their understanding of a wide range of financial terms and concepts to contexts that may only become relevant to their lives in the long term. They can analyse complex financial products and can take into account features of financial documents that are significant but unstated or not immediately evident, such as transaction costs. They can work with a high level of accuracy and solve non-routine financial problems, and they can describe the potential outcomes of financial decisions, showing an understanding of the wider financial landscape, such as income tax.

Source: (OECD, 2017[14])

Dataset

The data from the 2012, 2015 and 2018 financial literacy assessment are available at http://www.oecd.org/pisa/data/. The databases include, for the sampled students, their cognitive results in financial literacy and in standard PISA domains (mathematics and reading in PISA 2012 and 2018; mathematics, reading and science in PISA 2015), the behaviour data from the short questionnaire on financial literacy, and data from the general student questionnaire and school questionnaire (only in 2012).

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Notes

[1] PISA 2012 indicates that students with a parent working in the financial services sector have higher levels of financial literacy on average, although the data are only available for a limited number of countries.

4 PISA 2022 Creative Thinking Framework

Creative thinking refers to the cognitive processes required to engage in creative work. It is a key competence to assess in the context of PISA as it is a malleable individual capacity that can be developed through practice and that all students can demonstrate in everyday contexts. This section presents the framework for how the PISA 2022 assessment measures creative thinking, including how the construct is defined, the contexts in which it is assessed, and the approach to scoring student responses.

Why assess creative thinking in the 2022 PISA cycle?

Creative thinking is a key competence

Creativity has driven forward human culture and society in diverse areas, from the sciences and technology to philosophy, the arts and humanities (Hennessey and Amabile, 2010[1]). Organisations and societies around the world increasingly depend on innovation and knowledge creation to address emerging challenges (OECD, 2010[2]), giving urgency to innovation and creative thinking as collective enterprises.

Despite entrenched beliefs to the contrary, all individuals have the potential to think creatively (OECD, 2017[3]). Creative thinking is a tangible competence, grounded in knowledge and practice, that supports individuals (and groups) to achieve better outcomes – especially in constrained and challenging environments. Researchers and educators alike also agree that engaging in creative thinking can support a range of other skills including metacognitive, inter- and intra-personal and problem-solving skills, as well as promoting identity development, academic achievement, social engagement and career success (Barbot and Heuser, 2017[4]; Barbot, Lubart and Besançon, 2016[5]; Beghetto, 2010[6]; Higgins et al., 2005[7]; National Advisory Committee on Creative and Cultural Education, 1999[8]; Plucker, Beghetto and Dow, 2004[9]; Smith and Smith, 2010[10]; Spencer and Lucas, 2018[11]; Gajda, Karwowski and Beghetto, 2017[12]).

Assessing creative thinking in the Programme for International Student Assessment (PISA) can encourage a wider debate on the importance of supporting students' creative thinking through education, as well as encourage positive changes in education policies and pedagogies around the world. PISA data and instruments will provide policymakers with valid, reliable and actionable measurement tools that can support them in evidence-based decision making.

Creative thinking can and should be developed through education

A fundamental role of education is to equip students with the competences they need to succeed in life and society. Being able to think creatively is a critical competence that young people need to develop, including in school, for several reasons:

- Creative thinking helps prepare young people to adapt to a rapidly changing world that demands flexible and innovative workers equipped with "21st century skills" beyond numeracy and literacy. Children today will be employed in jobs that do not yet exist, responding to societal challenges that we cannot anticipate, and using new technologies. Developing creative thinking will help prepare them to adapt, undertake work that cannot easily be replicated by machines and address increasingly complex challenges with innovative solutions.
- The importance of creative thinking extends beyond the labour market, helping students to discover and develop their potential. Schools play an important role in students' holistic development and making them feel like they are part of the society they live in. Schools must therefore help young people to nurture their creative talents and empower them to contribute to the wider development of society (Tanggaard, 2018[13]).
- Creative thinking also supports learning by helping students to interpret experiences and information in novel and personally meaningful ways, even in the context of formal learning goals (Beghetto and Kaufman, 2007[14]; Beghetto and Plucker, 2006[15]). Student-centred pedagogies that engage students' creative thinking and encourage exploration and discovery can also increase students' motivation and interest in learning, particularly for those who struggle with rote learning and other teacher-centred schooling methods (Hwang, 2015[16]).

- Finally, creative thinking is important in a range of subject areas – from languages and the arts to science, technology, engineering and mathematics (STEM) disciplines. Creative thinking supports students to be imaginative, develop original ideas, think outside of the box and solve problems.

Just like any other ability, creative thinking can be nurtured through practical and targeted application (Lucas and Spencer, 2017[17]). Although developing students' creative thinking skills may imply taking time away from other subjects in the curriculum, creative thinking can be developed while promoting the acquisition of content knowledge in many contexts through approaches that encourage exploration and discovery rather than rote learning and automation (Beghetto, Baer and Kaufman, 2015[18]). Teachers need support in understanding how students' creative thinking can be recognised and encouraged in the classroom. The OECD's Centre for Educational Research and Innovation (CERI) leads a project whose aim is to support pedagogies and practices that foster creative and critical thinking.[1]

A principled assessment design process: Evidence-Centred Design as a guiding framework for the PISA 2022 Creative Thinking assessment

Evidence-Centred Design (ECD) (Mislevy, Steinberg and Almond, 2003[19]) provides a conceptual framework for developing innovative and coherent assessments that are built on evidence-based arguments, connecting what students do, write or create on a computer platform with multidimensional competences (Shute, Hansen and Almond, 2008[20]; Kim, Almond and Shute, 2016[21]). ECD starts with the basic premise that assessment is a process of reasoning from evidence to evaluate claims about students' capabilities. In essence, students' responses to the assessment items and tasks provide the evidence for this reasoning process and psychometric analyses establish the sufficiency of the evidence for evaluating each claim.

ECD provides a strong foundation for developing valid assessments of complex and multidimensional constructs. Adopting an ECD process for the PISA 2022 Creative Thinking assessment involved the following sequence of steps:

1) **Domain definition:** conducting a literature review and engaging with experts to define creativity and creative thinking in an educational context. This first step clarifies the creative thinking constructs that policy makers and educators wish to promote and identifies meaningful ways in which 15-year-old students can express creative thinking that can be feasibly assessed in PISA.
2) **Construct definition:** explicitly defining the assessment constructs and specifying the claims that can be made about test takers based on the assessment. In ECD terminology, this step is referred to as defining the Student Model (Shute et al., 2016[22]).
3) **Evidence identification:** describing the evidence (i.e. student behaviours or performances) that can support claims about test takers' proficiency in the target constructs. In ECD, this step is referred to as defining the Evidence Model and includes defining rules for scoring tasks and for aggregating scores across tasks.
4) **Task design:** designing and validating a set of tasks that can provide the desired evidence within the constraints of the PISA assessment. This stage corresponds to the Task Model step in ECD terminology.
5) **Test assembly:** assembling the tasks and units into test formats that support all the stated assessment claims with sufficient evidence. This corresponds to the Assembly Model step in ECD terminology.

ECD is an iterative assessment design process. For example, validation and pilot studies should, where relevant, inform further choices regarding evidence identification and task design. Validation and pilot studies are also crucial for ensuring that all assessment instruments provide reliable and comparable evidence across countries and cultural groups, which is especially important in the context of PISA. The remainder of this framework discusses each step of the ECD process in further detail for the PISA 2022 Creative Thinking assessment, before describing the approach to validation and reporting.

Defining the assessment domain: Understanding creativity and creative thinking

Creativity is a multidimensional construct

A principled assessment design process requires a strong theoretical foundation. Several researchers have established theories to describe the nature of creativity and to define creative people, processes and products. Broadly speaking, the literature defines creativity as "the interaction among aptitude, process and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (Plucker, Beghetto and Dow, 2004[9]).

Confluence approaches of creativity argue that individuals need several resources in order to produce creative work, including: 1) relevant knowledge and skills in a given field; 2) creative thinking processes; 3) task motivation; and 4) a supportive and rewarding environment (Amabile, 1983[23]; 2012[24]; Amabile and Pratt, 2016[25]). Some theories also include certain personality attributes as an important internal resource (Sternberg and Lubart, 1991[26]; 1995[27]; Sternberg, 2006[28]). These theories all understand creativity as a multidimensional construct that includes both relatively stable elements and elements that are more amenable to development and social influences. They also emphasise that it is the interaction, and not simply the availability (or not), of these resources that is important for engaging creatively with a given task. For example, low task motivation may prevent an individual from producing creative work despite domain expertise or a conducive environment.

These theories also understand the narrower construct of creative thinking as the important cognitive or "thinking" processes that enable individuals to produce creative outcomes.

Creativity can manifest in different types of ways

The literature on creativity generally distinguishes between "big-C" creativity and "little-c" creativity (Csikszentmihalyi, 2013[29]; Simonton, 2013[30]). "Big-C" creativity is associated with intellectual and/or technological breakthroughs, or artistic or literary masterpieces. These achievements demand that creative thinking processes be paired with significant talent, deep expertise in the given domain and high levels of engagement, as well as the recognition from society that the product has value.

Conversely, all people can demonstrate "little-c" (or "everyday") creativity by engaging in creative thinking. This type of everyday creativity might include arranging photos in an unusual way, combining leftovers to make a tasty meal or finding a solution to a complex scheduling problem. Overall, the literature agrees that "little-c" creativity can be developed through practice and honed through education (Kaufman and Beghetto, 2009[31]).

Creativity draws on both domain-general and domain-specific resources

Researchers in the field have long debated whether individuals are creative in everything they do or only in certain domains (i.e. a specific area of knowledge or practice). This debate naturally extends to creative thinking and raises an important question: is creative thinking in science different to creative thinking in writing or the visual arts, for example?

The first generation of creative thinking tests reflected the notion that a set of general and enduring attributes influenced creative endeavours of all kinds, and that an individual's capacity to be creative in one domain would readily transfer to another (Torrance, 1959[32]). However, more recent work tends to reject this generalist assumption.

Researchers now recognise that, to some extent, the internal resources needed to engage in creative work differ by domain (Baer, 2011[33]; Baer and Kaufman, 2005[34]). While agreement on the number of distinct "domains of creativity" remains an open research question, researchers have tended to agree that the capacity to engage creatively in the arts and in maths/scientific domains in particular draws upon a different set of internal resources (e.g. knowledge, skills, and attributes) (Kaufman and Baer, 2004[35]; Kaufman, 2006[36]; 2012[37]; Kaufman et al., 2009[38]; 2016[39]; Chen et al., 2006[40]; Julmi and Scherm, 2016[41]; Runco and Bahleda, 1986[42]).

Defining the construct for the PISA 2022 assessment

The PISA 2022 definition of creative thinking

While closely related to the broader construct of creativity, creative thinking refers to the cognitive processes required to engage in creative work. It is a more appropriate construct to assess in the context of PISA as it is a malleable individual capacity that can be developed through practice and does not place an emphasis on how wider society values the resulting output.

PISA defines creative thinking as *"the competence to engage productively in the generation, evaluation and improvement of ideas that can result in original and effective solutions, advances in knowledge and impactful expressions of imagination".* It builds on the definition first proposed by the Strategic Advisory Group (OECD, 2017[3]), tasked with providing some initial directions for the PISA 2022 assessment, and has been subsequently developed following a comprehensive review of the literature and the guidance of a wider interdisciplinary group of experts in the field.[2]

The PISA definition of creative thinking is aligned with the cognitive processes and outcomes associated with "little-c" creativity – in other words, it reflects the types of creative thinking that 15-year-old students around the world can reasonably demonstrate in "everyday" contexts. It emphasises that students need to learn to engage productively in generating ideas, reflecting upon ideas by valuing their relevance and novelty, and iterating upon ideas before reaching a satisfactory outcome. This definition of creative thinking applies to learning contexts that require imagination and the expression of one's inner world, such as creative writing or the arts, as well as contexts in which generating ideas is functional to the investigation of problems or phenomena.

Unpacking creative thinking in the classroom

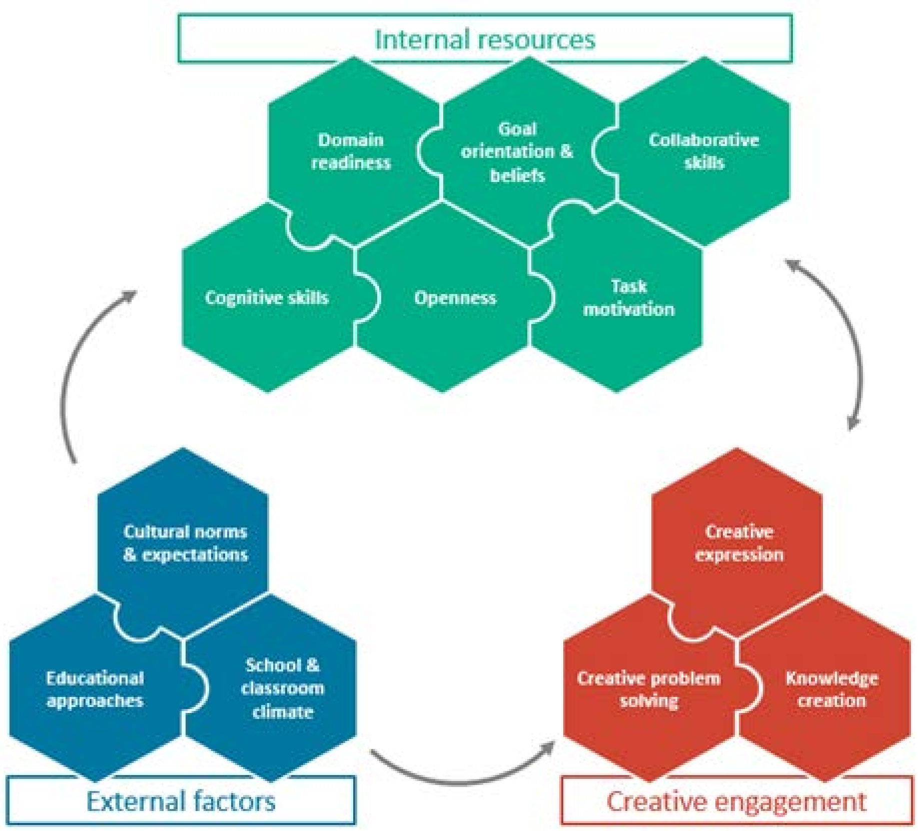
Confluence approaches of creativity emphasise that both "internal" and "external" resources are needed to successfully engage in creative work. To better understand children's creative thinking and define what information is important to collect in the PISA assessment, it is necessary to contextualise these approaches in a way that is relevant to students in their everyday school life (Glaveanu et al., 2013[43]; Tanggaard, 2014[44]). This section describes what creative thinking in the classroom looks like and the interconnected internal and external factors that can promote or hinder it.

Schools can influence many of the internal resources students need to engage in creative thinking. Internal resources here essentially refer to the set of knowledge, skills and attitudes that enable creative thinking. These include: 1) cognitive skills; 2) domain readiness (i.e. domain-specific knowledge and experience); 3) openness to new ideas and experiences; 4) goal orientation and self-belief; 5) task motivation; and 6) in some cases, collaborative skills. In terms of external factors, features of students' environments can also incentivise or hinder their capacity to engage in creative thinking. These include the classroom culture, the educational approach of schools and wider education systems, and broader cultural norms and expectations.

Schools are also important places in which students can think creatively, either as individuals or as part of a group, and where they can produce creative work. Creative achievement and progress in the classroom can take many forms, such as creative expression (communicating one's thoughts and imagination through various media), knowledge creation (advancing knowledge and understanding through inquiry), or creative problem solving.

Figure 4.1 summarises these elements that, together, define creative thinking in the classroom. The three sets of elements (internal resources, external factors, and creative achievement and progress) are strongly interconnected. For example, external factors includes cultural norms and expectations, which in turn influence how students' internal resources are developed and honed as well as the types of creative work that students might choose to produce. Each of the elements in Figure 4.1 are described in further in the following section.

Figure 4.1. Unpacking creative thinking in the classroom: internal resources, external factors, and types of creative engagement



Internal resources

Cognitive skills

Both convergent thinking and divergent thinking (Guilford, 1956[45]) are widely recognised as important skills for creative thinking. Convergent thinking refers to the ability to apply conventional and logical reasoning to information (Cropley, 2006[46]). As such, convergent thinking aids in understanding the problem space and identifying and evaluating good ideas (Reiter-Palmon and Robinson, 2009[47]; Runco, 1997[48]). By contrast, divergent thinking refers to the ability to think of original ideas, to make flexible connections ideas or pieces of information, and to apply fluency of association and ideation (Cropley, 2006[46]). It also refers to the ability to break out of "fixed" performance scripts – in other words, to try new approaches, to look at problems from different angles, and to discover new methods of "doing" (Schank and Abelson, 1977[49]; Duncker, 1972[50]). In essence, divergent thinking brings forth novel, unusual or surprising ideas.

Creative thinking is often described in terms of divergent thinking and most assessments to-date have focused on measuring divergent thinking cognitive processes. However, convergent thinking cognitive processes are also important for engaging in creative work. For example, Getzels and Csikszentmihalyi (1976[51]) found that art students' success in "problem construction" was strongly correlated with measures of the originality and aesthetic value of their resulting paintings, and that these measures were also linked to long-term artistic success.

Domain readiness

Domain readiness conveys the idea that some prior domain knowledge and experience is needed to successfully produce creative work (Baer, 2016[52]). A better understanding of a domain is more likely to help with generating and evaluating ideas that are both novel and useful (Hatano and Inagaki, 1986[53]; Schwartz, Bransford and Sears, 2005[54]). However, this relationship may not be strictly linear – well-established routines for deploying knowledge or skills within a domain may also result in idea fixation and a reluctance to think beyond those established routines.

Openness to experience and intellect

Several studies have shown that creative people share a core set of tendencies, particularly the "Big Five" personality dimension of "openness" (Kaufman et al., 2009[38]; 2016[39]; McCrae, 1987[55]; Prabhu, Sutton and Sauser, 2008[56]; Werner et al., 2014[57]).[3] In general, such empirical studies examining the personality and behaviour of creative individuals have typically employed questionnaire instruments that operationalise creativity as a relatively enduring and stable personality trait (Hennessey and Amabile, 2010[1]). Meta-analyses of studies on creativity and personality have also found that openness appears to be a common trait in creative achievers across domains, whereas other personality traits tend to interact with creativity only insofar as they benefit individuals within specific domains (e.g. "conscientiousness" seems to enhance scientific creativity but detract from performance in the arts) (Batey and Furnham, 2006[58]; Feist, 1998[59]).

Both "openness to experience" and "openness to intellect" are included under the broader openness trait. "Openness to experience" describes an individual's receptivity to engage with novel ideas, imagination and fantasy (Berzonsky and Sullivan, 1992[60]). Its predictive value for creative achievement across domains is likely due to its inclusion of cognitive (e.g. imagination), affective (e.g. curiosity) and behavioural aspects (e.g. adventurousness), and the links between curiosity and creativity have been further supported by several researchers (Chávez-Eakle, 2009[61]; Feist, 1998[59]; Guastello, 2009[62]; Kashdan and Fincham, 2002[63]).

"Openness to intellect" describes an individual's receptivity to appreciate and engage with abstract and complex information, primarily through reasoning (DeYoung, 2014[64]). In contrast to "openness to experience", which is particularly correlated with artistic creativity, the trait "openness to intellect" seems particularly correlated with scientific creativity (Kaufman et al., 2016[39]).

Goal orientation and creative self-beliefs

Persistence, perseverance and creative self-efficacy influence creative thinking by providing a strong sense of goal orientation and the belief that creative goals can be achieved. Investing effort towards one's goal and overcoming difficulty are essential for engaging in creative thinking, as they enable individuals to maintain concentration for long periods and deal with frustrations that arise (Cropley, 1990[65]; Torrance, 1988[66]; Amabile, 1983[23]).

Related to goal orientation is creative self-efficacy, which describes an individual's beliefs that they are capable of successfully producing creative work (Beghetto and Karwowski, 2017[67]). Researchers consider creative self-efficacy essential in determining whether an individual will sustain effort towards their goals in the face of resistance and ultimately succeed in performing tasks creatively (Bandura, 1997[68]). These beliefs can in turn be influenced by one's prior experience and performance history, mood and environment (Bandura, 1997[68]; Beghetto, 2006[69]).

Task motivation

The role of task motivation as a driver of creative work has been well documented, namely in the works of Teresa Amabile (1997[70]; 2016[25]; 2010[1]; 1983[23]). The basic notion is that, as with any task, an individual will not produce creative work unless they are sufficiently motivated to do so. This motivation can be both intrinsic and extrinsic.

Intrinsic task motivation drives individuals who find their work inherently meaningful or rewarding, for reasons such as enjoyment, self-interest or a desire to be challenged. This type of task engagement is relatively insensitive to incentives or other external pressures. The experience of "creative flow" – being fully immersed in a task and disregarding other needs – is a powerful driver of creativity because individuals in flow are intrinsically motivated to engage in a task (Csikszentmihalyi, 1996[71]; Nakamura and Csikszentmihalyi, 2002[72]).

On the other hand, extrinsic task motivation refers to external incentives, goals, or pressures that motivate people to engage in a particular task. Although research emphasises the importance of intrinsic task motivation in creative performance, extrinsic motivators such as deadlines or recognition can also motivate people to persist in their creative endeavours (Eisenberger and Shanock, 2003[73]; Amabile and Pratt, 2016[25]).

Collaborative engagement

Creative work often results from interactions between individuals and their environment – including interactions with others. Research has also increasingly examined creative thinking as a collective endeavour, for example by examining the actions of teams in generating new knowledge (Thompson and Choi, 2005[74]; Prather, 2010[75]; Grivas and Puccio, 2012[76]; Scardamalia, 2002[77]). Collaboration can help individuals to explore and build upon the ideas of others as well as improve weaknesses in ideas. This can drive forward knowledge creation by facilitating the development of solutions to complex problems that are beyond the capabilities of any one person (Warhuus et al., 2017[78]).

External factors

Cultural norms and expectations

Creative work is embedded within social contexts that are inherently shaped by cultural norms and expectations. Cultural norms and expectations can influence the skills that individuals develop, the values that shape personality development, and the differences in performance expectations within societies (Niu and Sternberg, 2003[79]; Wong and Niu, 2013[80]; Lubart, 1998[81]). Some studies have investigated how cultural differences affect national measures of creativity and innovation, concluding that differences along the individualism-collectivism spectrum can significantly shape how creative work is defined and valued (Rinne, Steel and Fairweather, 2013[82]; Ng, 2003[83]).

Educational approaches

Cultural norms affect educational approaches, in particular the outcomes an education system values for its students and the content it prioritises in the curriculum. In some cases, these approaches might actively discourage creative thinking and achievement at school (Wong and Niu, 2013[80]). For example, the pressures of standardisation and accountability in educational testing systems often reduce opportunities for creative thinking in schoolwork (DeCoker, 2000[84]). Some have even claimed that increasingly narrow educational approaches and assessment methods are at the root of a "creaticide" affecting today's young people (Berliner, 2011[85]). Schools and educational systems therefore play an important role in combatting this effect and should seek to implement policies and practices that increase the opportunities and rewards for producing creative work (and decrease the associated costs).

Classroom climate

Beyond broader cultural norms and educational systems, certain classroom practices can also stifle creative thinking – for example, perpetuating the idea that there is only one way to learn or solve problems, cultivating attitudes of submission and fear of authority, promoting beliefs that originality is a rare quality, or discouraging students' curiosity and inquisitiveness (Nickerson, 2010[86]). Conversely, findings from organisational research has demonstrated that informal feedback, goal setting, teamwork, task autonomy, and appropriate recognition and encouragement to develop new ideas are all important enablers of creative thinking (Amabile, 2012[24]; Zhou and Su, 2010[87]). It could be argued that similar findings could also apply to creative thinking in the classroom.

Teachers' beliefs about creativity are also important: they need to value creative work and consider it a fundamental skill that should be developed in the classroom. Teachers can actively cultivate an environment that helps students learn when creative thinking is appropriate and how to take charge of their own creativity – for example, by encouraging students to set their own goals, identify promising ideas, and take responsibility for contributing to creative teamwork (Beghetto and Kaufman, 2010[88]; 2014[89]). Employing "questions of wonderment" – or encouraging students to try to understand the world and put forth their ideas about different phenomena – can also help to promote knowledge creation in the classroom (Bereiter and Scardamalia, 2010[90]). These approaches are all supported by teachers' beliefs that creative thinking is something that can be developed in the classroom, even if this development takes time.

Creative engagement

Creative products are both novel and useful, as defined within a particular social context. Examining the outputs of students' creative work can provide indicators of their capacity to think creatively, particularly in tasks where much of the creative thinking process is not visible (Amabile, 1996[91]; Kaufman and Baer, 2012[92]). Students can produce different kinds of "everyday" creative work at school, either as individuals or as part of a group. These forms of creative work in the classroom are multi-disciplinary and extend beyond traditional subjects.

Creative expression

Creative expression refers to both verbal and non-verbal forms of creative engagement where individuals communicate their thoughts, emotions and imagination to others. Verbal expression involves the use of language, including both written and oral communication, whereas non-verbal expression includes drawing, painting, modelling, music, and physical movement and performance.

Knowledge creation

Knowledge creation refers to the advancement of knowledge and understanding, with a focus on making progress rather than achievement per se (e.g. improving an idea rather than achieving the optimal solution or complete understanding). Knowledge creation refers not only to important discoveries or advancements but also to the purposeful act of building upon and iterating on ideas that can happen at all levels of society and across all knowledge domains (Scardamalia and Bereiter, 1999[93]).

Creative problem solving

Not all cases of problem solving require creative thinking: creative problem solving is a distinct class of problem solving characterised by novelty, unconventionality, persistence and difficulty during problem formulation (Newell, Shaw and Simon, 1962[94]). Creative thinking becomes particularly necessary when students are challenged to solve problems outside of their realm of expertise and where the techniques with which they are familiar do not work (Nickerson, 1999[95]).

Implications of the domain and construct analysis for the test and task design

Objective and focus of the PISA 2022 Creative Thinking assessment

The PISA 2022 assessment focuses on the creative thinking processes that can be reasonably demonstrated by 15-year-old students. It does not aim to single out exceptionally creative individuals but describe the extent to which students are capable of thinking creatively when searching for and expressing ideas and explore how this capacity is related to teaching approaches, school activities and other features of education systems.

The main objective of PISA is to provide internationally comparable data on students' creative thinking competence that have clear implications for education policies and pedagogies. The creative thinking processes in question therefore need to be malleable through education; the different factors enabling these thinking processes in the classroom context need to be clearly identified and related to performance in the assessment; and the assessment tasks need to align with the subjects and activities undertaken by students so that the test has some predictive validity of creative achievement and progress in school and beyond.

Assessment instruments: cognitive test and questionnaire modules

The PISA 2022 Creative Thinking assessment is composed of two parts: a cognitive test and a background questionnaire. PISA students who receive the creative thinking test will complete tasks that require them to generate, evaluate and improve ideas in different contexts. The test therefore focuses on gathering information about students' cognitive skills involved in creative thinking. The background questionnaire module for creative thinking will gather data on students' attitudes (openness, goal orientation and beliefs), perceptions of their school environment, and activities they participate in both inside and outside the classroom. Teachers and school leaders will also provide information about their beliefs about creativity and the activities offered in their schools.

Together, these assessment instruments will gather information on the complex set of factors that influence creative thinking in the classroom (students' internal resources, external factors, and creative achievement and progress). However, some factors will be better measured than others: for example, while collaborative skills can influence knowledge creation in the classroom, students' capacities to engage in collaborative creative thinking will not be directly measured in the PISA 2022 assessment (although some test tasks do ask students to evaluate and improve the work of others).

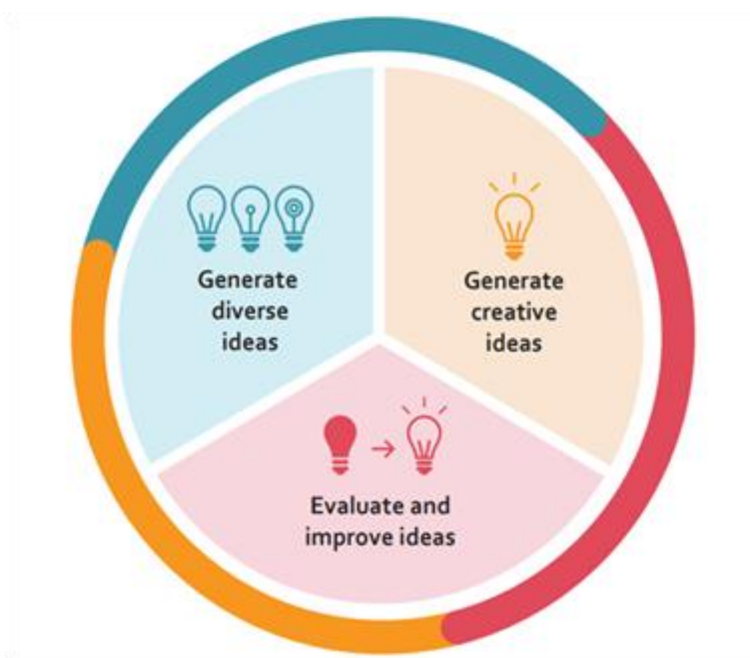
Measuring creative thinking in the PISA test: task design and scoring approach

The competency model of creative thinking

The competency model shown in Figure 4.2 illustrates how the creative thinking construct has been decomposed into three distinct facets for measurement purposes in the PISA 2022 test. These three facets are: 1) generate diverse ideas; 2) generate creative ideas; and 3) evaluate and improve ideas. These three facets reflect the PISA definition of creative thinking and encompass the cognitive skills required for creative thinking in the classroom. The competency model incorporates both divergent cognitive processes (the ability to generate diverse ideas and to generate creative ideas) and convergent cognitive processes (the ability to evaluate other people's ideas and identify improvements to those ideas).

"Ideas" in the context of the PISA assessment can take many forms. The test units provide a meaningful context and sufficiently open tasks in which students can demonstrate their capacity to produce different ideas and think outside of the box.

Figure 4.2. Competency model for the PISA 2022 test: three facets of creative



Generate diverse ideas

Typically, attempts to measure creative thinking have focused on the number of ideas that individuals are able to generate – often referred to as “ideational fluency”. Going one step further is “ideational flexibility”, or the capacity to generate ideas that are different to each other. When it comes to measuring the quality of ideas that an individual generates, some researchers have argued that fundamentally different ideas should be weighted more than similar ideas (Guilford, 1956[45]).

The facet ‘generate diverse ideas’ of the competency model encompasses these ideas and refers to a student’s capacity to think flexibly by generating multiple distinct ideas. Test items for this facet will present students with a stimulus and ask them to generate two or three appropriate ideas that are as different as possible from one another.

Generate creative ideas

The literature generally agrees that creative ideas and outputs are defined as being both novel and useful. Clearly, expecting 15-year-olds around the world to generate ideas that are completely unique or novel is neither feasible nor appropriate for the PISA assessment. In this context, originality is a useful concept as a proxy for measuring the novelty of ideas. Defined by Guildford (1950[96]) as “statistical infrequency”, originality encompasses the qualities of newness, remoteness, novelty or unusualness, and generally refers to deviance from patterns that are observed within the population at hand. In the PISA assessment context, originality is therefore a relative measure established with respect to the responses of other students who complete the same task.

The facet ‘generate creative ideas’ focuses on a student’s capacity to generate appropriate and original ideas. “Appropriate” means that ideas must comply with the task requirements and demonstrate a minimum level of usefulness. This dual criterion ensures the measurement of creative ideas – ideas that are both original and of use – rather than ideas that make random associations that are original but not meaningful. Test items for this facet will present students with a stimulus and ask them to develop one original idea.

Evaluate and improve ideas

Evaluative cognitive processes help to identify and remediate deficiencies in initial ideas as well as ensure that ideas or solutions are appropriate, adequate, efficient and effective (Cropley, 2006[46]). They often lead to further iterations of idea generation or the reshaping of initial ideas to improve a creative outcome. Evaluation and iteration are thus at the heart of the creative thinking process. Being able to provide feedback on the strengths and weaknesses of others’ ideas is also an essential part of any collective knowledge creation effort.

The facet ‘evaluate and improve ideas’ focuses on a student’s capacity to evaluate limitations in ideas and improve their originality. To reduce problems of dependency across items, students are not asked to iterate upon their own ideas but rather modify someone else’s work. Test items for this facet will present students with a given scenario and idea and ask them to suggest an original improvement, defined as a change that preserves the essence of the initial idea but that adds or incorporates original elements.

Domains of creative thinking

The literature suggests that the larger the number of domains included in an assessment of creative thinking, the better the coverage of the construct. However, certain practical and logistical constraints limit the number of possible domains that can be included in the PISA 2022 assessment of creative thinking. These constraints include:

- **The age of test takers.** 15-year-olds have limited knowledge and experience in many domains, meaning those included in the assessment must be familiar to most students around the world and must reflect realistic manifestations of creative thinking that 15-year-olds can achieve in a constrained test context.
- **The available testing time.** Students will sit a maximum of one hour of creative thinking items, meaning the range of possible domains must be limited to ensure sufficient data are collected from tasks in each domain. As PISA aims to provide comparable measures of performance at the country level rather than the individual level, it is possible to apply a rotated test design in which students take different combinations of tasks within domains.
- **The available testing technology.** The PISA test is administered on standard desktop computers with no touchscreen capability or Internet connection. Although the test platform supports a range of item types and response modes, including interactive tools and basic simulations, the choice of domains and the design of the tasks needed to take into consideration the technical limitations of the platform.

Taking these main constraints into account and building upon the literature exploring different domains of creativity, the PISA 2022 test includes tasks situated within four distinct domain contexts: 1) written expression; 2) visual expression; 3) social problem solving; and 4) scientific problem solving. The written and visual expression domains involve communicating one's imagination to others, and creative work in these domains tends to be characterised by originality, aesthetics, imagination, and affective intent and impact. In contrast, social and scientific problem solving involve investigating and solving open problems. They draw on a more functional employment of creative thinking that is a means to a better end, and creative work in these domains is characterised by ideas or solutions that are original, innovative, effective and efficient.

These four domains represent a reasonable and sufficiently diverse coverage of the different types of "everyday" creative thinking activities in which 15-year-olds engage. Given that differences in cultural preferences exist for certain forms of creative engagement as do differences in what is valued in education across the world, in addition to the fact that creative engagement in each domain is supported by some degree of domain readiness, we can also expect variation in student performance across domains. By having students work on more than one domain during the test, it will be possible to gain insights on country-level strengths and weakness by domain of context. Each of the four domain contexts are described in further detail below.

Written expression

Creative writing involves communicating ideas and imagination through written language. Good creative writing requires that readers understand and believe in the author's imagination, including the rules of logic within the universe the author has created. Both fictional and non-fictional writing can be creative and learning how to express oneself creatively can help students to develop effective and impactful communication skills that they will need throughout their lifetimes.

In the PISA test students express their imagination in a variety of written formats. For example, students will caption an image, propose ideas for a short story using a given text or visual as inspiration, or will write a short dialogue between characters for a movie or comic book plot.

Visual expression

Visual expression involves communicating ideas and imagination through a range of different media. Creative visual expression has become increasingly important as the ubiquity of desktop publishing, digital imaging and design software means that nearly everyone will need to design, create or engage with visual communications at some point in their personal or professional lives.

In the PISA test, students express their imagination by using a digital drawing tool. The drawing tool does not enable free drawing, but students can create visual compositions by dragging and dropping elements from a library of images and shapes. Students are also able to resize, rotate and change the colour of elements. Students will create visual designs for a variety of purposes, such as creating a clothing design, logo or poster for an event.

Social problem solving

Young people use creative thinking every day to solve personal, interpersonal and social problems. These problems can range from the small-scale, personal level (e.g. resolving a scheduling conflict) to the wider school, community or even global levels (e.g. finding ways to improve sustainable living). Creative thinking in this domain involves understanding different perspectives, addressing the needs of others, and finding innovative and functional solutions for the parties involved (Brown and Wyatt, 2010[97]).

In the PISA test, students solve open problems that have a social focus. These problems focus on issues that affect groups within society (e.g. young people) or on issues that affect society at large (e.g. the use of global resources or the production of waste materials). Students are asked to propose ideas or solutions in response to a given scenario, or to suggest original ways to improve others' solutions.

Scientific problem solving

Scientific problem solving involves generating new ideas and understanding, designing experiments to probe hypotheses, and developing new methods or inventions (Moravcsik, 1981[98]). Students can also demonstrate creative thinking as they engage in a process of scientific inquiry by exploring and experimenting with different ideas or materials to make discoveries and advance their knowledge and understanding (Hoover, 1994[99]).

Although creative thinking in science is related to scientific inquiry, the tasks in this domain differ fundamentally from the PISA scientific literacy tasks. In this test, students are asked to generate multiple distinct ideas or solutions, or an original idea or solution, for an open problem for which there is no pre-defined correct response. In other words, the tasks measure students' capacity to produce diverse and original ideas not their ability to reproduce scientific knowledge or understanding. For example, in a task asking students to formulate different hypotheses to explain a phenomenon, they would be rewarded for proposing multiple plausible hypotheses regardless of whether one of those hypotheses constituted the right explanation for the phenomenon. Nonetheless, domain readiness may affect performance in this domain more than others as most tasks that can be imagined imply a minimum level of knowledge of basic scientific principles.

In the PISA test, students engage with open problems that have a scientific or engineering basis. Students are asked to propose hypotheses to explain a given scenario, or to improve or generate new methods for solving problems.

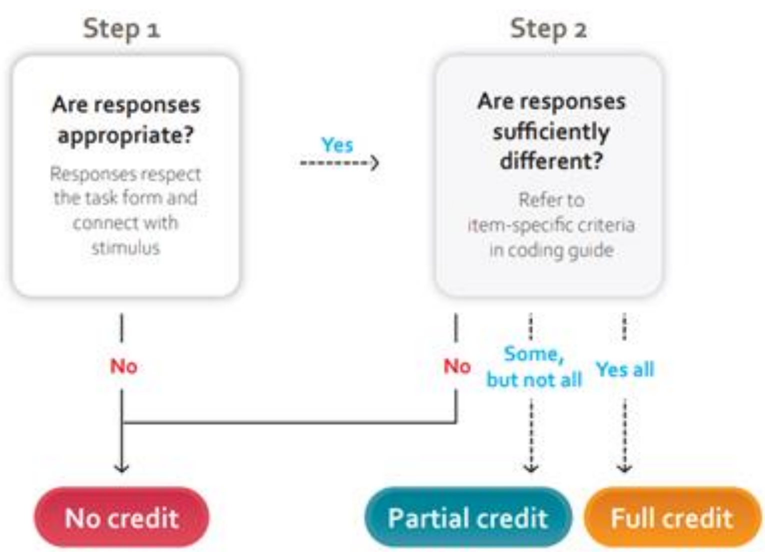
Scoring the tasks

Every task in the PISA test is open-ended, meaning there are essentially infinite ways of demonstrating creative thinking. Scoring for this assessment therefore relies on human judgement following detailed scoring rubrics and well-defined coding procedures. All items corresponding to the same facet of the competency model apply the same general coding procedure. However, as the form of response varies by domain and task (e.g. a title, a solution, a design, etc.), so do the item-specific criteria for evaluating whether an idea is different or original. The detailed coding guides describe the item-specific criteria for each item and provide annotated example responses to help human coders score consistently.

Scoring of ‘generate diverse ideas’ items

All items corresponding to the ‘generate diverse ideas’ facet of the competency model require students to provide two or three responses. The general coding procedure for these items involves two steps, as summarised in Figure 4.3. First, coders must determine whether responses are appropriate**.** Appropriate in the context of this assessment means that students’ responses respect the required form and connect (explicitly or implicitly) to the task stimulus. Second, coders must determine whether responses are sufficiently different from one another based on item-specific criteria described in the coding guide**.**

Figure 4.3**. General coding process for ‘generate diverse ideas’ items**



The item-specific criteria are as objective and inclusive as possible of the range of different potential responses. For example, for a written expression item, sufficiently different ideas must use words that convey a different meaning (i.e. are not synonyms). For items in the problem-solving domains, the coding guides list pre-defined response categories to help coders distinguish between similar and different ideas. The coding guides provide detailed example responses and explanations for how to code each example.

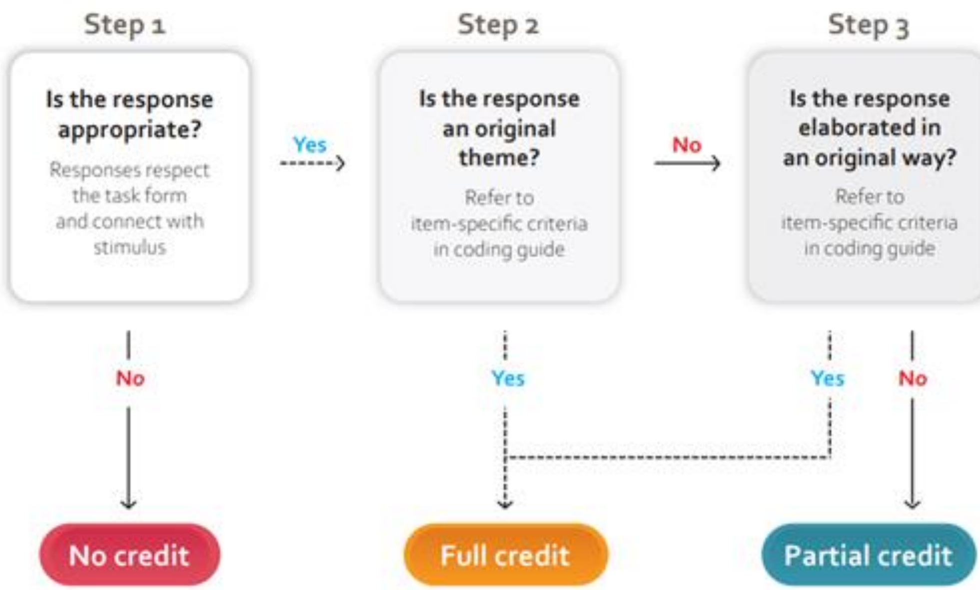
Full credit is assigned where all the responses required in the task are both appropriate and different from each other. Partial credit is assigned in tasks requiring students to provide three responses, and where two or three responses are appropriate but only two are different from each other. No credit is assigned in all other cases.

Scoring of ‘generate creative ideas’ items

All items corresponding to the facet ‘generate creative ideas’ of the competency model require a single response. The general coding procedure for these items involves two or three steps, depending on the content of the response. First, as with all items, coders must determine whether the response is appropriate. Then, coders must determine whether the response is original by considering two criteria (see Figure 4.4).

An original idea is defined as a relatively uncommon idea with respect to the entire pool of responses. The coding guide identifies one or more conventional themes for each item according to the patterns of genuine student responses revealed in multiple validation studies. If a response does not correspond to a conventional theme as described in the coding guide, it is directly coded as original. However, if an idea does correspond to a conventional theme, then coders must determine whether it is original based on its elaboration. The coding guide provides item-specific explanations and examples of original ways to elaborate on conventional themes. For example, a student might add an unexpected twist to a story idea that otherwise centres on a conventional theme.

Figure 4.4. **General coding process for 'generate creative ideas' and 'evaluate and improve' items**



This twofold originality criteria ensures that the scoring model takes into account both the general idea and the details of a response. While this approach does not single out the most original responses in the entire response pool, it does ensure that the coding process is less susceptible to culturally-sensitive grading styles that favour middle points or extremes, and it provides some mitigation against potential cultural bias in the identification of conventional themes across countries.

Full credit is assigned where the response is both appropriate and original. Partial credit is assigned where the response is appropriate only, and no credit is assigned in all other cases.

Scoring of 'evaluate and improve ideas' items

All items corresponding to the facet 'evaluate and improve ideas' of the competency model require a single response and generally ask students to adapt a given idea in an original way rather than coming up with an idea from scratch. The general coding procedure for these items involves the same steps as those for the 'generate creative ideas' items, described above and in Figure 4.4.

However, appropriate responses for these items must be both relevant and constitute an improvement. The threshold for achieving the appropriateness criteria for these items is thus somewhat strengthened with respect to items measuring the other two facets, as responses must explicitly connect to the task stimulus and attempt to address its deficiencies. The coding guide provides item-specific criteria, examples and explanations to help orient coders. For responses considered appropriate, coders must establish the originality of the improvement by considering the same two originality criteria as for 'generate creative ideas' items.

Full credit is assigned where the response is both appropriate and an original improvement. Partial credit is assigned where the response is appropriate only, and no credit is assigned in all other cases.

Assembling the test

Test and unit design

Students who receive a creative thinking module will spend up to one hour on creative thinking items, with the remaining hour of testing time assigned to a combination of mathematics, reading or scientific literacy items. The creative thinking items are organised into units, which in turn are organised into 30-minute "clusters". Each cluster includes two or more test units. The clusters are placed in multiple computer-based test formats according to a rotated test design.

Each creative thinking unit contains between one and three items, and the items are organised around a common stimulus or context. The units vary in several important ways including:

- **The facets of the construct** (generate diverse ideas, generate creative ideas, evaluate and improve ideas) that are measured by the items in the unit;
- **The domain context** in which the items are situated (written expression, visual expression, social problem solving or scientific problem solving);
- **The unit length** (guidelines of 5 to 15 minutes).

While not every unit provides a point of observation for every facet of the construct, the rotated test design and the balanced variation of facets within different domain contexts ensures that, as a whole and at the population level, the test provides an adequate coverage of all the facets of creative thinking as defined by the competency model. The balanced coverage of items across the four domains will also make it possible to explore the extent to which students who demonstrate proficiency in creative thinking in one domain can also demonstrate proficiency in other domains.

Refining the item pool for the PISA 2022 Main Survey

Over the course of the test development cycle, several test units were designed, developed and piloted within the PISA testing platform, including during the limited PISA 2020 Field Trial and the full PISA 2021 Field Trial. Not all units and items that were designed or developed progressed to the Field Trial stage of test development (e.g. if the item performed poorly in earlier validation studies, development may have stopped at this point). The test units and items that progressed to the final pool of units for the PISA 2022 Main Survey were selected from this wider pool of potential units with the support of country reviewers and the Expert Group, and informed by the following key criteria:

- The representation of key concepts for creative thinking (e.g. facets of the competency model, domains), as identified in the framework;
- The range of tasks that can accurately discriminate proficiency;
- The appropriateness and variety of the task types;
- The ability to produce reliable coding and scoring;
- The familiarity and relevance of topics to all students, independent of their country and socio-cultural context;
- Their performance in the cognitive labs, validation studies and Field Trial(s).

Validating the tasks and scoring methods

As with any PISA assessment, but particularly the PISA innovative domain assessments, it is paramount to ensure sufficient validation throughout the test conceptualisation and development phases. There are several sources of potential measurement invariance for any large-scale international assessments. In the context of PISA, some of the most important include: 1) the similarity of the relevance and definition of the construct being measured across cultures; 2) students' familiarity with the item format used in the test (e.g. interactive or static units, or different response types); 3) the relevance, clarity and familiarity of the item content; and 4) the quality of adaptation into different languages. The failure to investigate these aspects through validation exercises leads to the introduction of test bias and ultimately to structural and measurement non-equivalence across the groups under study (Van de Vijver and Leung, 2011[100]).

Given the complex nature of measuring creative thinking, the assessment framework, test tasks and questionnaire items, scoring materials and coder training practices have undergone extensive validation. This has included several rounds of review of the assessment materials by PISA participating countries, cognitive laboratories in 2 countries, small-scale pilot data collections in 5 countries and two Field Trial data collections (one partial and one large-scale). The following section describes the different ways in which the OECD Secretariat and the test development contractor have addressed issues of validity and comparability for the PISA 2022 Creative Thinking assessment in further detail, both through test design and development practices and through the collection and analysis of data.

Optimising cross-cultural validity and comparability of the construct (construct equivalence)

Construct equivalence refers to the degree to which the construct definition is similar for populations targeted by the assessment. The literature emphasises that creativity is embedded within social contexts, and research has found that the way creativity develops and the ways in which it manifests can differ across cultural groups (Lubart, 1998[81]; Niu and Sternberg, 2003[79]). Careful attention has thus been paid to balance measurement validity with score comparability for the PISA assessment, namely by focusing the assessment on certain aspects of the construct that optimise comparability across cultures. These include:

1. **Focusing on the narrower construct of creative thinking**, defined as being able to engage productively in the generation, evaluation and improvement of ideas. This narrower focus emphasises the cognitive processes related to idea generation, whereas the broader construct of creativity also encompasses personality traits and requires more subjective judgements about the creative value of students' responses;
2. **Defining creative thinking and its enablers in the context of 15-year-olds in the classroom**, focusing on aspects of the construct that are more likely to be developed in schooling contexts around the world rather than outside of school;
3. **Identifying cross-culturally relevant domains** in which 15-year-olds are likely to be able to engage and can be expected to have practiced creative thinking;
4. **Focusing scoring on the originality** (i.e. statistical infrequency) **and diversity of ideas** (i.e. belonging to different categories), rather than the creative value or quality of ideas (that are more likely to be subject to sociocultural bias).

In addition, the assessment framework – which defines the construct and its operationalisation for the PISA 2022 assessment – has been developed under the guidance of a multicultural and multidisciplinary Expert Group with expertise in the field of creativity and its measurement, as well as subject to multiple rounds of review by PISA participating countries.

Ensuring cross-cultural validity and comparability of the tasks (test equivalence)

Test equivalence refers to the equivalence of tasks and test versions in different languages and for different student groups, including the degree to which different student groups perceive and engage with the tasks in the same way. Several activities were undertaken during the test development phase to address potential sources of test equivalence in the tasks and scoring methods, including:

1) **Cross-cultural face validity and comparability reviews.** Experts in the measurement of creative thinking and PISA participating countries engaged in several cycles of review of the test material and coding guides to validate the task contexts, stimuli and scoring criteria. These review exercises helped to identify and eliminate possible sources of cultural, gender and linguistic bias prior to the collection of data.

2) **Cognitive laboratories.** Experienced test development professionals conducted cognitive laboratories with students around the age of 15 years-old in three PISA participating countries across three continents. Students simulated completing the test units and responded to a series of questions in a "think aloud" protocol while working through the test material, explaining their thought processes and pointing out misunderstandings in the instructions or task stimuli. Problematic task content, features or instructions were subsequently modified.

3) **Small-scale validation exercises.** Genuine student data were collected, coded and scored in a series of small-scale pilot studies simulating PISA testing conditions (3 separate data collections across 5 countries). The analysis of the data and the coding processes in each of the studies identified items that did not perform as intended, informing iterative, evidence-based improvements to the test material, coding guide and scoring procedures.

4) **Translatability reviews.** Experienced test development, adaptation and translation professionals conducted translatability reviews to ensure that all of the assessment materials (items, stimuli and coding guides) could be sufficiently and appropriately translated into the many languages used in the PISA Main Study. This included ensuring a balanced adaptation of the linguistic and cultural references associated with each language group in PISA.

5) **Field Trial(s) and Main Study data analysis and verification.** The Field Trial, undertaken in all PISA participating countries, provides an opportunity for a full construct and measurement validation exercise prior to the Main Study. The Field Trial simulates the administration of the assessment to large representative samples of 15-year-olds across the world. Analysis of the Field Trial data is used to exclude test items that demonstrate insufficient validity and score reliability, within and across countries, in addition to differential item functioning. Given the importance of human coding for this assessment, the Field Trial also allowed a first, full-scale validation of the coding processes including the inter-rater reliability (see Box 1). Due to the global disruption to schooling caused by the COVID-19 pandemic, the PISA 2021 Main Study was postponed to 2022; a partial Field Trial was therefore conducted in 2020, followed by a full Field Trial in 2021. Analysis of the data collected in the Main Study also enabled further verification of the data quality in terms of score reliability, validity and differential item functioning. The frequency distribution of response themes across countries was also examined following the Main Study data collection, informing adjustments to the coding and scoring rules for some items to maximise cross-cultural comparability.

Box 4.1. Investigating inter-rater reliability

Ensuring the reliability and comparability of scores is a fundamental principle in all PISA assessments. In the PISA 2022 Creative Thinking assessment, the success of the scoring approach clearly depends on the quality of the scoring rubrics, coding guides and clear coding processes. The scoring rubrics and coding guides underwent a rigorous process of verification throughout the test development cycle, with input from coders in PISA participating countries on the content and language used in the coding materials. Experienced test development and scoring professionals also led several international coder training workshops to train the coders in PISA participating countries ahead of both 2020 and 2021 Field Trials, as well as the 2022 Main Study.

Inter-rater reliability (i.e. the extent to which two or more coders agree on the code assigned to a response) was also investigated in all of the validation activities that involved the collection and scoring of student responses, in line with established PISA practices, in order to understand and address issues of consistency by improving the item design or the coding guidance. In the Field Trial(s), within-country inter-rater reliability was measured by having multiple coders code a set of randomly selected 100 responses for each item. Across-country inter-rater reliability was measured by asking English-speaking coders in each country to code a set of 10 anchor responses selected from responses of real students in different countries for each item. Sufficient inter-rater reliability, as approved by the PISA Technical Advisory Group (TAG) of experts, was recorded for all items that progressed to the 2022 Main Study item pool.

The PISA background questionnaires for creative thinking

In addition to the test, PISA gathers self-reported information from students, teachers and school principals through the use of questionnaire instruments. In the PISA 2022 cycle, these questionnaire instruments will collect information about the different enablers and drivers of creative thinking outlined earlier in this framework document that are not directly measured in the test.

Curiosity and exploration

Questionnaire items will measure students' curiosity, openness to new experiences and disposition for exploration. Questionnaire scales on openness were informed by the extensive literature on the relationship between personality and creativity as well as the existing inventory of self-report measures that have been used in previous empirical studies to identify "creative people".

Creative self-efficacy

Students will complete items measuring the extent to which they believe in their own creative abilities, focusing on their general confidence in thinking creatively as well as their beliefs about how well they are able to think creatively in different domains.

Beliefs about creativity

One scale in the questionnaire explores various beliefs students have about creativity in general. The items ask students whether they believe creativity can be trained or it is an innate characteristic, whether creativity is only possible in the arts, whether being creative is inherently positive, and whether they hold other beliefs that might influence their motivation to learn to be creative. A similar scale also asks teachers to report their beliefs about creativity in general, including whether they value creativity and whether they belief it can be trained.

Creative activities in the classroom and at school

The student questionnaire asks students about the activities in which they participate, both inside and outside of school, which might contribute to their domain readiness and attitudes towards different creative domains. The school principal and teacher questionnaire will also gather information about creative activities included in the curriculum and offered to students in extracurricular time.

Social environment

The student, teacher and school principal questionnaires collect information about students' school environments. Questionnaire items focus on student-teacher interactions (e.g. whether students believe that free expression in the classroom is encouraged) as well as the wider school ethos. These items can provide further information on the role of extrinsic motivation on student creative performance (e.g. students' perception of discipline, time pressures, or assessment).

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Notes

[1] Since 2015, CERI has explored the teaching and assessment of creative thinking in several countries, including Brazil, France, Hungary, India, the Netherlands, Russia, the Slovak Republic, Spain, Thailand, the United Kingdom (Wales) and the United States. Drawing on earlier work by Lucas, Claxton and Spencer (2013[103]), the project developed a teacher-friendly framework to describe creative and critical thinking in classrooms in primary and secondary education as well as rubrics to support the development of pedagogical activities to support students’ creative and critical thinking.

[2] The Strategic Advisory Group defined creative thinking as "…the process by which we generate fresh ideas. It requires specific knowledge, skills and attitudes. It involves making connections across topics, concepts, disciplines and methodologies". It builds on the five-dimensional model proposed by Lucas, Claxton and Spencer (2013[102]) that describes the dispositions and "habits of mind" of creative individuals and that was designed for use in the classroom.

[3] The "Big Five" personality traits, also referred to as the Five Factor Model of personality traits, include five distinct traits: Openness to experience; Conscientiousness; Extraversion; Agreeableness; and Neuroticism (McCrae and Costa, 1987[101]).

5 PISA 2022 Context Questionnaire Framework: Balancing Trends and Innovation

This chapter presents the framework for the background core questionnaires for students and schools and explains the goals and rationale for selecting specific questionnaire content for the eighth cycle of PISA. Like prior frameworks, it touches upon how measured constructs theoretically relate to one another and to student achievement. Additionally, the framework outlines a set of survey design principles and methodologies that are introduced to PISA 2022 with the aim of improving measurement, efficiency, and consistency of PISA in the mid to long term.

Glossary

To ensure consistent understanding of specific terms and acronyms used throughout this framework, Table 5.1 below lists key terms used throughout the framework along with brief definitions. Table 5.2 lists and clarifies acronyms used throughout the framework.

Table 5.1. Glossary of key terms

Term	Definition
Construct	A theoretically defined conceptualization (i.e., something constructed) of an aspect of human behaviour or an empirical phenomenon; a construct has empirical indicators but may not be completely observable due to deficits of existing measures. Two broad content categories of constructs are distinguished in the framework: (1) those that are specific to a PISA 2022 content domain (i.e., mathematics, reading, science, creative thinking) and (2) those that are general (i.e., not specific to a PISA 2022 content domain). Each construct is operationally measured by multiple items.
Item	The unit(s) of a question that a respondent answers. In case of a stand-alone discrete question, the item is the same as the question. In case of a matrix question, one question includes several items.
Matrix Question	A question that consists of a question stem and several items with the same response options.
Module	A grouping of two or more related constructs that mark a key topic or theme measured with the PISA 2022 questionnaires.
Question	The parts of a questionnaire designed to elicit information from a respondent. In PISA, the question can take the form of a stand-alone discrete question or a matrix question. When presented in the PISA digital platform, each question appears on a single screen.
Question Stem	The component of a question that presents a leading sentence clarifying what the respondent is being asked to consider when answering each item.
Questionnaire Matrix Sampling Design	A questionnaire design where each respondent receives only a subset of items in the entire questionnaire. In a *within-construct* matrix sampling design, a respondent answers items for all constructs but only receives a subset of items for each construct. In contrast, in a *construct-level* matrix sampling design entire constructs are rotated across questionnaire booklets.
Response Options	A typically verbally labelled set of answer choices provided to respondents for close-ended multiple-choice questions.
Scaled Index	An index or measure based on the scaling (using item response theory) of multiple items that all are indicators of the same underlying construct.

Table 5.2. Glossary of acronyms

Acronym	Term
CIPO	Context-Input-Process-Output Model
CT	Creative Thinking
ESCS	PISA index of Economic, Social, and Cultural Status
FT	PISA Field Trial
GCM	PISA Global Crises Module
ICQ	PISA Information and Communication Technology Questionnaire
IRT	Item Response Theory
ISCED	International Standard Classification of Education
ISCO	International Standard Classification of Occupations
LSA	Large-scale Assessment
MEG	PISA Mathematics Expert Group
MS	PISA Main Survey
OECD	Organisation for Economic Co-operation and Development
OTL	Opportunity to Learn
PGB	PISA Governing Board
PISA	Programme for International Student Assessment
PISA-D	PISA for Development
QEG	PISA Questionnaire Expert Group
SCQ	PISA School Questionnaire
SES	Socioeconomic Status

SSES	OECD Survey of Social and Emotional Skills
STQ	PISA Student Questionnaire
TAG	PISA Technical Advisory Group
TALIS	OECD Teaching and Learning International Survey
WBQ	PISA Well-being Questionnaire

Introduction

Aims of the PISA Questionnaires

Large-scale Assessments (LSAs) play an important role in evaluating education systems in terms of their capacity to develop human potential, advance progress and the quality of life of individuals across the globe and prepare future workforces for 21st century demands. Since its inception in the late 1990s, the Programme for International Student Assessment (PISA) has been known for its important contribution to education policy discussions within the Organisation for Economic Co-operation and Development (OECD) and partner countries and economies.

The main features of PISA are as follows:

- PISA is a *system-level assessment*, representing a commitment by governments to monitor the outcomes of education systems.
- PISA is *policy-oriented*, linking data on students' learning outcomes with data on key factors that shape learning in and out of school.
- PISA is *carried out regularly*, enabling countries and economies to monitor their progress in meeting key learning objectives.
- PISA *assesses both subject matter knowledge*, on the one hand, and *the capacity of individuals to apply that knowledge creatively*, including in unfamiliar contexts, on the other.
- PISA focuses on *knowledge and skills towards the end of compulsory schooling*. In most countries and economies, the end of compulsory education is around the age of 15, where students are supposed to have mastered the basic skills and knowledge to continue to higher education or the workforce.
- PISA is designed to *provide comparable data across a wide range of countries and economies.* Considerable efforts are devoted to achieving cultural and linguistic breadth and balance in assessment materials.
- PISA is a *collaborative effort* involving multiple parties including the OECD, PISA Governing Board (PGB), OECD member countries, and partner countries and economies.

PISA continues to yield indicators of the effectiveness, efficiency, and equity of educational systems, setting benchmarks for international comparison and monitoring trends over time. PISA also builds a sustainable database that allows researchers worldwide to study basic as well as policy-oriented questions on education, including those related to society and economy. The OECD and the PGB continue to look for ways to increase the scientific quality and policy relevance of the PISA context questionnaires to meet these needs.

Since the first cycle of PISA in 2000, the student and school context questionnaires have performed two interrelated purposes in service of the broader goal of evaluating educational systems:

- first, the questionnaires provide a context for interpreting the PISA results both within and between education systems;
- second, the questionnaires aim to provide reliable and valid measurement of *additional educational constructs*, which can further inform policy and research.

Over the seven cycles of PISA to date, education policy discussions have shifted from a heavy focus on the first objective to an increased focus on the second aim as well. This development corresponds to a shift in policymakers' views of the core goals for education systems in the 21st century, away from primarily teaching clearly defined subject knowledge and skills, to fostering broader skills (such as creativity, communication, collaboration, or learning to learn) that help individuals face the demands of a technology-rich and truly global society (UN, 2015[1]). There is now a growing recognition that other factors and competencies aside from subject-specific knowledge play a vital role in fostering students' success in school and beyond. In order to understand and guide policy decisions regarding student development, the PISA 2022 context questionnaires will strengthen the measurement of the contexts that promote learning in these areas, as well as an array of general constructs of policy relevance.

The COVID-19 pandemic that emerged globally in early 2020 will likely have short- and long-term impacts on schooling and students' learning in these areas. The PISA 2022 context questionnaires will therefore also collect information on COVID-19-related disruptions to students' learning and well-being in participating education systems. This information can provide context for understanding PISA 2022 results, as well as serve to advance policy discussions about fostering the resiliency of students, schools, and education systems in responding to educational disruptions arising from ongoing and future global crises.

Outline of the PISA 2022 Context Questionnaire Framework

The PISA 2022 context questionnaire framework explains the goals and rationale for selecting specific questionnaire content for the eighth cycle of PISA. Like prior frameworks, the present framework touches upon how measured constructs theoretically relate to one another and to student achievement. Additionally, the framework outlines a set of survey design principles and methodologies that are introduced to PISA 2022 with the aim of improving measurement, efficiency, and consistency of PISA in the mid to long term. To achieve these goals, the framework is structured as follows:

- *Section 2.* describes a set of general considerations that led to the development of this framework and that guided instrument development for PISA 2022. These considerations included priorities for re-administration of questions from previous PISA cycles, changes to the mathematics framework since PISA 2012 that needed to be considered when prioritizing questionnaire constructs, country-specific needs across the range of participating countries and economies, directions taken with the PISA 2022 innovative domain of creative thinking, and plans for optional questionnaires.
- *Section 3.* presents the PISA 2022 two-dimensional framework taxonomy. The first dimension classifies proposed constructs into the two overarching categories distinguished by the PGB (domain-specific constructs and general constructs, with the latter including Economic, Social, and Cultural Status [ESCS]). The second dimension classifies proposed constructs into five categories based on key areas of educational policy setting at different levels of aggregation (Student Background; Student Beliefs, Attitudes, Feelings, and Behaviours; Teaching Practices and Learning Opportunities; School Practices, Policies, and Infrastructure; and Governance, System-Level Policies and Practices). Linkages between the 2022 approach and the overarching cross-cycle structure developed across the PISA 2000 – 2018 questionnaire frameworks are highlighted, with a focus specifically on the past three PISA cycles, i.e., 2012, 2015, and 2018 (OECD, 2013[2]; Klieme, 2014[3]; OECD, 2013[4]).
- *Section 4.* gives a detailed overview of the questionnaire modules and constructs measured in the MS which were selected for inclusion based on analysis of FT data and discussion of priorities among experts and policy makers (including the PGB).
- *Section 5.* summarizes the survey design principles that guided the PISA 2022 questionnaire development process, subsequent FT administration, and post-FT analyses and item selections for the MS.

Balancing re-administration of questions from previous cycles with new development

For PISA 2022, the PGB recommended re-balancing questionnaire content in the direction of a larger focus on general constructs and a slightly reduced focus on domain-specific constructs. Specifically, the PGB suggested that 40% of the content be devoted to domain-specific constructs. The remaining 60% of content focused on general constructs would be split between 20% devoted to measuring ESCS and 40% focused on other general constructs, including additional outcomes (PISA Governing Board, 2017[5]). By contrast, in 2018 the balance of questionnaire content across domain-specific constructs, ESCS, and general constructs was 50%, 17%, and 33%, respectively.

It was suggested that percentages be allocated based on estimated questionnaire administration time. For the PISA 2022 MS, of the allocated testing time for the student questionnaire (STQ) is 35 minutes. That is, approximately seven minutes of the STQ is devoted to ESCS and 14 minutes each are devoted to domain-specific and general constructs. Within the boundaries of these overall strategic priorities, two key areas of consideration guided the development of the PISA 2022 context questionnaire framework: (1) re-administration of questions from previous PISA cycles and (2) new development.

Guidelines for re-administration of questions from previous years

A key force driving the PISA design in general is the cyclical change of focus in the cognitive assessment. Mathematics was the major domain of cognitive assessment in PISA 2003 and 2012 and is the major domain again in 2022. Reading was the major domain of assessment in PISA 2000, 2009, and 2018. Science was the focus of PISA 2006 and 2015. The major domain serves as the primary focus of domain-specific content in the associated PISA context questionnaires (e.g., various mathematics-related constructs marked the focus of the 2003 and 2012 questionnaires).

In order to describe educational constructs of interest over time at the country or economy level, it is desirable to maintain a stable set of questionnaire measures that can be used as major reporting variables across PISA cycles. Given the cyclical nature of PISA, measurement stability can be considered at two levels:

- first, there is the issue of stability of measures across cycles of three years (i.e., administration of items for constructs that may appear in every cycle, e.g. ESCS);
- second, stability is desirable in measuring domain-specific constructs across cycles of nine years (i.e., mathematics-specific constructs assessed in the 2012 and/or 2003 cycles).

A priority of PISA 2022 has been to retain a reasonable number of questions that have been administered in previous PISA questionnaires. Table 5.3. summarizes guidelines used for decisions about retention or deletion of previously administered PISA items.

Table 5.3. Guidelines for retention or deletion of PISA questions from previous cycles

Guidelines for retention or deletion of PISA questions from previous cycles
1. Retain questions that best explain variations in academic achievement within and across countries;
2. Retain questions that are of highest policy relevance and/or necessary to establish or extend trend lines, which can inform policy and research;
3. Where possible and sensible, carry forward constructs intact, or with only minor changes that improve measurement precision;
4. Delete or revise questions that are outdated (e.g., questions that reference resources or technologies that are no longer in use);
5. Delete or revise questions that do not meet PISA 2022 psychometric criteria established by the Technical Advisory Group (TAG); and
6. Delete or shorten questions that provide information that is redundant with other questions or items within a matrix question.

Guidelines for new development

PISA has been making efforts to innovate in educational measurement. Over its past cycles, the program has, for instance, introduced new technologies (e.g., computer-based assessment [CBA]); expanded into measuring new innovative domains (e.g., collaborative problem solving in 2015, global competency in 2018, and creative thinking in 2022); updated its view on the measurement objectives for its major domains based on new frameworks; and has reacted to the emergence of new policy priorities (e.g., measuring student health and well-being as well as other social and emotional characteristics; measuring the impact of COVID-19-related disruptions on student learning and well-being).

For PISA 2022, the scope of the mathematics framework has been expanded to evaluate students' mathematical reasoning grounded in six core concepts or "big mathematical ideas" that undergird the specific content, skills, and algorithms of school mathematics (PISA Governing Board, 2017[5]):

1. Quantity, number systems and their algebraic properties;
2. Mathematics as a system based on abstraction and symbolic representation;
3. Mathematical structure and its irregularities;
4. Functional relationships between quantities;
5. Mathematical modelling as a lens onto the real world (e.g., those arising in the physical, biological, social, economic, and behavioural sciences); and
6. Variation as the heart of statistics.

Students will also be assessed in their familiarity with, or prior classroom exposure to, four emerging areas of mathematics content in which reasoning skills need to be applied: computer simulations, growth phenomena, conditional decision making, and geometric approximation. The questionnaire framework has been updated accordingly to better understand students' opportunities to learn these concepts, as well as the extent to which 21st century skills are emphasized in mathematics instruction.

Additionally, creative thinking will be assessed as the innovative domain in PISA 2022. A distinct module of the PISA 2022 context questionnaires is devoted to constructs that contribute to the understanding of students' performance in this innovative domain.

Several new educational systems will participate in PISA beginning in 2022, many of which belong to lower- and middle-income countries. In order to maximize the value of PISA to these participants, the context questionnaires include constructs related to student background and learning contexts that have previously been described in the PISA for Development (PISA-D) framework (OECD, 2018[6])

New development makes use of informed practices in survey methodology (e.g., principles regarding item types, response options, balancing of scales, length of matrix questions) and technological capabilities (e.g., routing, matrix sampling) to the extent that they enhance measurement. Section 5 of this framework elaborates on the survey design principles that guided PISA 2022 questionnaire development.

While this framework focuses on the conceptual underpinnings of the PISA questionnaires for students and schools, additional frameworks that are not part of this document provide in-depth theoretical foundation for additional questionnaires included in PISA 2022 as part of international options (i.e., frameworks for Financial Literacy, Information and Communication Technology [ICT] Literacy, Student Well-being, Teacher Well-being).

Table 5.4. summarizes guidelines used for considering the addition of new items for existing constructs as well as entirely new constructs in PISA 2022.

Table 5.4. Guidelines for new development

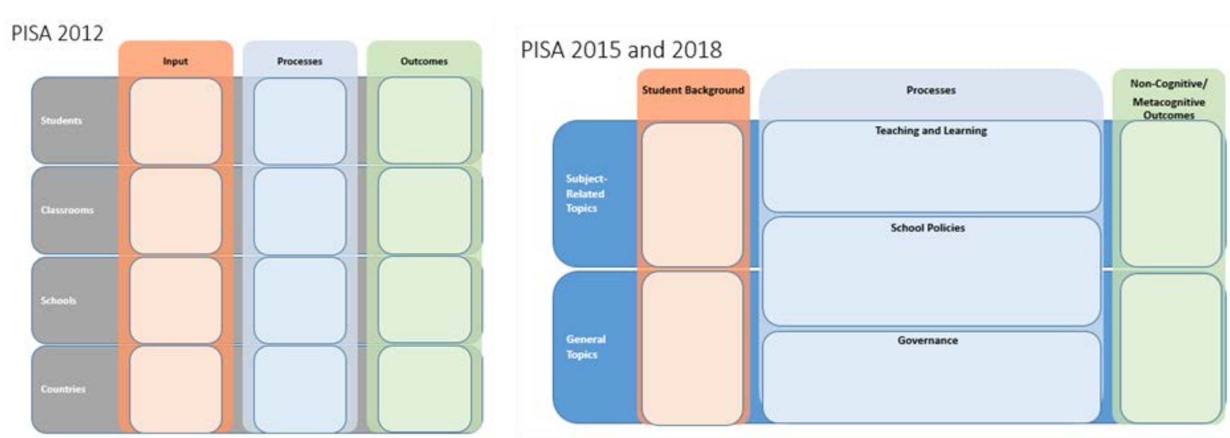
Guidelines for addition of new items for existing constructs as well as entirely new constructs
1. Develop questions for new constructs that are central to the educational research literature and the PGB priorities;
2. Develop new questions that are relevant to changes to the PISA mathematics framework (e.g., addition of mathematical reasoning);
3. Develop new questions for constructs that are related to the innovative domain assessed in PISA 2022 (i.e., creative thinking);
4. Develop new questions to replace previously used questions that do not comply with PISA 2022 psychometric criteria, substantially violate PISA 2022 survey design principles, and/or require updates to more accurately describe students' living and learning realities;
5. Develop new questions to replace previously used questions that do not offer sufficient flexibility to meet country- or region-specific needs of all participating education systems; and
6. Develop new questions to help shed light on the impact of the COVID-19 pandemic on student learning and well-being, and the degree of interruptions or changes to education across participating education systems.

PISA 2022 Context Questionnaire Framework taxonomy

Beginning with the questionnaire framework used for the PISA 2009 assessment, questionnaire content was explicitly linked to different levels of the education system: the student level, level of instruction in the classroom, school level, and system level (Jude, 2016). The questionnaire framework used for PISA 2012, and subsequently refined for PISA 2015 and 2018, further underscored the importance of collecting information on learning contexts for comparative system monitoring. These frameworks outlined an overarching two-dimensional structure of high-level questionnaire content areas to be measured and kept comparable across assessment cycles (OECD, 2013[4])

The theoretical foundation of the 2012 overarching framework is based on Purves' (1987[7]) *Context-Input-Process-Outcome* (CIPO) model. In the CIPO model, contextual variables for understanding education systems are conceptualized as a series of inputs (i.e., student background), processes (i.e., teaching and learning, school policies, governance), and outcomes (i.e., performance and non-cognitive outcomes) shaped at the student, classroom, school, and country levels. Starting with PISA 2015 and 2018, an additional dimension further classified questions more explicitly into domain-specific and domain-general modules. Domain-specific modules represent the set of constructs with strong expected relationships to student experiences, outcomes, and teaching and learning factors tied to a specific content area (e.g., reading, mathematics, or science). Domain-general modules represent the set of constructs that are important for understanding differences in achievement that are not tied to a specific subject-area. Figure 5.1 illustrates the high-level structures of the context questionnaire frameworks from 2012, 2015, and 2018.

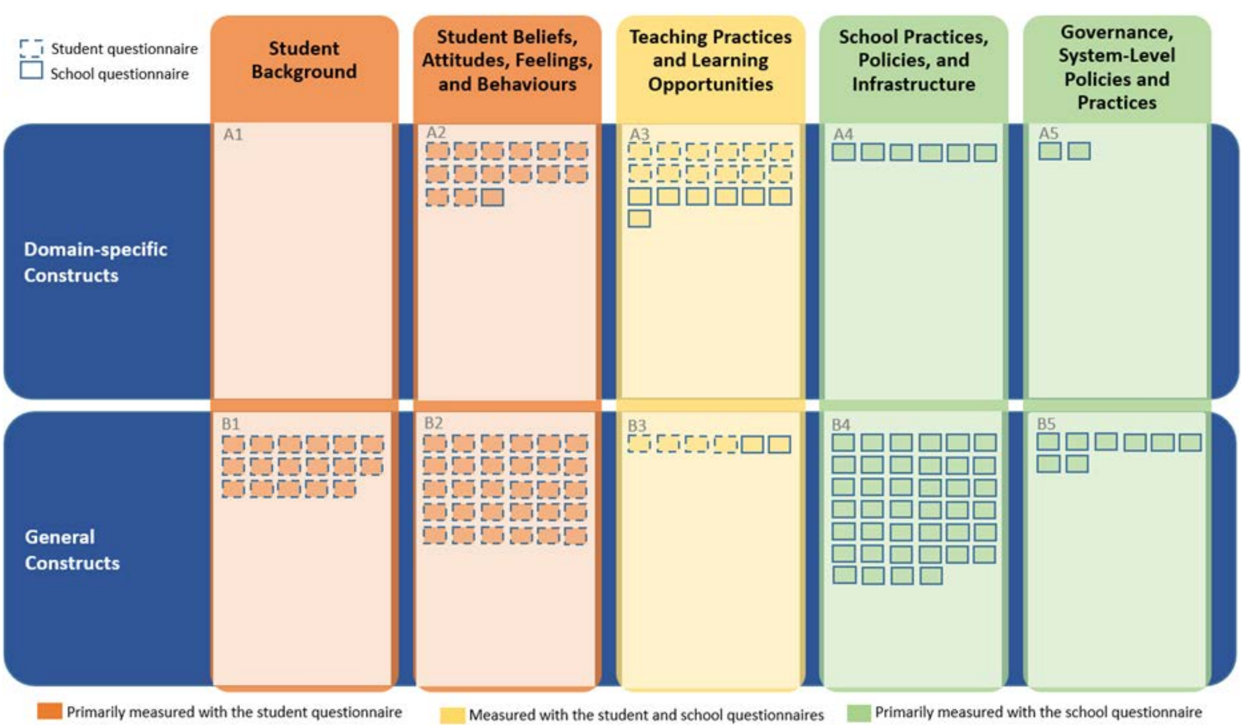
Figure 5.1. Framework structures of PISA 2012, 2015, and 2018



In keeping with the long-term goal of balancing continuity with innovation, the PISA 2022 context questionnaire framework retains key framework elements from previous cycles as a foundation, and introduces refinements that facilitate the strategic development of new constructs and move toward improved measurement. This updated framework structure is illustrated in Figure 5.2 below. Please note, while performance and contextual variables have been classified as "outcomes" in previous PISA frameworks per the CIPO model, both types of variables also constitute possible inputs (OECD, 2013[4]). For instance, a student's prior achievement and his/her curiosity, perseverance, achievement motivation, or confidence will likely impact the student's future achievement, as well as his/her future development of social and emotional characteristics. Due to the cross-sectional nature of PISA, variables collected through the questionnaires cannot be clearly assigned a single "role". While the CIPO model remains useful to describe an actionable policy perspective and serve as a helpful theoretical perspective for researchers on the variables measured with the PISA questionnaires, it seems less useful as a guide to classify and prioritize variables for instrument development. Due to the ambiguity in classifying variables, constructs are *not* classified as inputs, processes, or outcomes in the PISA 2022 framework taxonomy. Instead, we allude to the possible roles each variable might play in the detailed descriptions of each module. Further description of the framework dimensions and the modules is provided in subsequent sections of this framework.

Across the two overarching (vertical) framework content dimensions and of the five (horizontal) policy focus areas as shown in Figure 5.2, a total of 21 modules are specified (see Section 4. of this document). The small boxes in the taxonomy below indicate the relative distribution of constructs in the PISA 2022 MS across all modules described in this framework.

Figure 5.2. PISA 2022 two-dimensional Context Questionnaire Framework taxonomy



Classification based on relationships to PISA content domains

As outlined above, the PISA 2022 student and school questionnaires serve two interrelated purposes (i.e., to provide contextual information and provide additional measures) in service of the broader goal of evaluating the effectiveness of all educational systems participating in the 2022 MS.

The two categories along the vertical dimension of the taxonomy in Figure 5.2 represent the primary types of content in the student and school questionnaires:

1. *Domain-specific* Constructs; and
2. *General* Constructs (including ESCS).

Both categories of constructs represent questions that are included in PISA primarily to report their relationships with academic achievement and provide a context for interpreting the PISA results within and between education systems, as well as constructs that are included in PISA primarily to report additional variables that describe educational systems beyond academic achievement to inform policy and research.

Domain-specific constructs

Domain-specific constructs include constructs that demonstrate a relationship to students' academic achievement in the major domain of the current cycle (i.e., mathematics for PISA 2022) or hold power to explain broader outcomes in the major domain, such as students' educational career and post-secondary aspirations (e.g., course enrolment, outlook on future educational career). Examples of indicators include mathematics-related school curricula or students' interest and motivation to learn mathematics topics. Constructs that are included primarily to better understand differences in achievement in the PISA 2022 mathematics achievement scores were evaluated empirically after the FT according to their relationship with mathematics achievement to determine their inclusion in the PISA 2022 MS. The mathematics-specific constructs included in the PISA 2022 MS are summarized in Table 5.5 bellow.

In addition to constructs related to the major domain (i.e., mathematics), a smaller number of contextual variables specific to all three domains (including the two minor domains of this assessment cycle, Reading and Science) are included in the PISA 2022 MS questionnaires to provide relevant contextual information for student achievement. Lastly, the category of domain-specific constructs includes several creative thinking-related constructs that aim to contextualize achievement results in the PISA 2022 innovative domain.

Table 5.5. Mathematics-specific constructs in PISA 2022 Student and School Questionnaires

Student Questionnaire Mathematics Constructs
Subjective familiarity with mathematics concepts
Exposure to formal and applied mathematics tasks
Exposure to mathematics reasoning and 21st century mathematics topics
Perceived quality of mathematics instruction
Disciplinary climate in mathematics
Cognitive activation in mathematics: Encourage mathematical thinking
Cognitive activation in mathematics: Foster reasoning
Class periods per week in mathematics
Time spent on homework
Participation in additional mathematics instruction (types)
Mathematics teacher support
Growth mindset
Favourite subjects and self-concept in mathematics, test language, and science
Mathematics self-efficacy: Formal and applied mathematics

	Mathematics self-efficacy: Reasoning and 21st century mathematics
	Mathematics anxiety
	Effort and persistence in mathematics
School Questionnaire Mathematics Constructs	
	Use of mathematics achievement data in accountability systems
	Standardised mathematics curriculum
	Use of mathematics assessments
	Average time in class period
	Average number of students in mathematics classes
	Selection of courses
	Percent of students who received marks below, at/above the pass mark in mathematics class their last school report
	Student ability grouping in mathematics
	School offering additional mathematics lessons
	Mathematics teacher qualifications
	Mathematics teacher training

General constructs

General constructs include constructs that demonstrate relationships to students' academic achievement across multiple domains, such as students' feelings towards school (e.g., student-teacher relationships, bullying experiences), school infrastructure (e.g., availability of digital technology for learning), or constructs that complement traditional indicators of educational effectiveness (e.g., subjective well-being, social and emotional characteristics). General constructs also include ESCS to assess students' socioeconomic status (SES) and the equity of educational opportunities within and across educational systems.

Classification based on Educational Policy Areas

The horizontal dimension of the taxonomy distinguishes five categories of educational policy focus that correspond to different aggregate levels for the collected survey responses, from individual-level variables to highly aggregated system-level indicators:

1. Student background;
2. Student beliefs, attitudes, feelings, and behaviours;
3. Teaching practices and learning opportunities;
4. School practices, policies, and infrastructure; and
5. Governance, system-level policies and practices.

Student background

The first educational policy area of interest relates to *Student Background.* In order to understand students' education pathways and to study equity within and across educational systems, basic demographic variables (e.g., gender, age, or grade), constructs related to ESCS, migration and language background, as well as information about students' early years must be considered. The distribution of educational opportunities and outcomes correlated with these background constructs may provide data about whether countries succeed in providing equity in educational opportunities.

Student beliefs, attitudes, feelings, and behaviours

The second educational policy area of interest focuses on *Student Beliefs, Attitudes, Feelings, and Behaviours.* In addition to measuring 15-year-olds' academic achievement in reading, mathematics, science, and creative thinking, measures of students' subjective attitudes and feelings, as well as their behavioural choices may provide important indicators for an education system's success in fostering productive members of society.

Beliefs include constructs such as beliefs about learning or student's mindsets. Attitudes include constructs such as students' attitudes towards mathematics, or attitudinal aspects of social and emotional characteristics. Feelings concern feelings about their school or about specific subject-areas, and emotional aspects of social and emotional characteristics. Behaviours include participation in activities outside of school or behavioural aspects of social and emotional characteristics. Constructs such as respecting and understanding others, being motivated to learn and collaborate, or being able to regulate one's own behaviour may play a role as prerequisites of acquiring subject-area knowledge and skills. In addition, such characteristics may also be judged as goals of education in their own right (Almlund et al., 2011[8]; Bertling, Marksteiner and Kyllonen, 2016[9]; Heckman, Stixrud and Urzua, 2006[10]; Rychen and Salganik, 2003[11]).

Each of the past seven PISA cycles have included a significant number of questions tapping into students' beliefs, attitudes, feelings, and behaviours related to the major domain. In addition, recent PISA cycles have increased their focus on general constructs (e.g., "Noncognitive outcomes" modules in PISA 2015 and PISA 2018). PISA 2022 carries these developments forward and includes several modules addressing a range of constructs such as students' effort on the PISA test and questionnaires (Module 5), students' general school-related attitudes and feelings associated with school climate (Module 6), attitudes towards specific PISA content domains (Module 7), and students' general social and emotional characteristics (Module 8). A broad range of student behaviours are further assessed via a module focused on out-of-school experiences (Module 10). In addition, students' subjective views on their socioeconomic standing, as well as their future aspirations and well-being, are captured in modules 2, 3, and 9, respectively.

Teaching practices and learning opportunities

The third educational policy area of interest pertains to *Teaching Practices and Learning Opportunities.* Classroom-based instruction is the immediate and core setting of formal, systematic education. Therefore, policy makers need information on the organisation of classrooms and the teaching and learning experiences that occur within them. The knowledge base of educational effectiveness research (e.g. (Scheerens and Bosker, 1997[12]; Creemers and Kyriakides, 2007[13]) allows for the identification of core variables with an expected bearing on mathematics and student achievement in general, for example, teachers' qualifications, teaching practices and classroom climate, learning time, and learning opportunities provided in and outside of school. As such, this policy area closely links to the idea of *opportunity to learn* (OTL), which was first introduced by Carroll (Carroll, 1963[14])to indicate whether students have had sufficient time and received adequate instruction to learn (Abedi, 2006[15]). Though the meaning of OTL has since broadened, it has been an important concept in international student assessments (e.g., (Schmidt, 2001[16]) and shown to be strongly related to student performance in cross-country comparisons (Schmidt, 2009[17]).

Researchers have suggested defining OTL not only based on subject-specific teacher instruction (Callahan, 2005[18]; McDonnell, 1995[19]); and have stressed the importance of evaluating the quality of instruction in addition to mere quantity (Duncan and Murnane, 2011[20]; Little and Bell, 2009[21]; Minor et al., 2015[22]). Researchers have also pointed out the importance of informal learning opportunities and experiences in the home (Lareau and Weininger, 2003[23])and highlighted the need to evaluate OTL in country-specific contexts (Cogan and Schmidt, 2014[24]). Accounting for these broader directions, OTL could be defined as all contextual factors that capture the cumulative learning opportunities a student has been exposed to at the time of the assessment (Bertling, Marksteiner and Kyllonen, 2016[9]). These contextual factors may comprise both learning opportunities at school and informal and formal learning opportunities outside of school. In this framework, several aspects of OTL are captured across different modules, including modules capturing opportunities provided through the ways in which student learning is organised (Module 14), opportunities defined based on the mathematics content students are exposed to (Module 15), and opportunities created based on the behaviours teachers exhibit in the classroom (Module 16).

School practices, policies, and infrastructure

The fourth educational policy area of interest examines *School Practices, Policies, and Infrastructure.* As policymakers have limited direct impact on teaching and learning processes, information on school-level factors (e.g., practices, policies, and infrastructure) that help to improve schools, and thus indirectly improve student learning, are a priority. In addition to individual student demographics and structural factors (such as school location, school type, and school size), the social, ethnic, and academic composition of the school influences students' learning processes and outcomes. Therefore, PISA uses aggregated student data to characterize demographic and other contextual factors at the level of the school community.

Similar to the *Teaching Practices and Learning Opportunities* modules and constructs, school effectiveness research has reported that "essential supports" are associated with school effectiveness (Bryk et al., 2009[25]). These essential supports include leadership and school management; well-organised curriculum, instructional, and enrolment policies; tangible resources; positive school climate; and parent or guardian involvement. Educational psychologists also emphasise teachers' collective efficacy, principals' leadership, parent or guardian involvement, and peer support as crucial for creating a positive school climate conducive to learning (LEE and SHUTE, 2010[26]). Many of these factors have been previously addressed in the PISA questionnaires as domain-general processes on the school level. Also covered is school-level support for teaching the major domain, such as the provision of learning resources and space, information and communication technology (ICT), and a school curriculum for mathematics education.

Governance, system-level policies and practices

Finally, the fifth educational policy area of interest focuses on *Governance, System Level Policies and Practices.* To meet policy requests directly, PISA also needs to address issues related to governance at the system level (Hanushek and Woessmann, 2011[27]). For instance, assessment and evaluation are basic processes that policy makers and/or school administrators use to control school quality, and to monitor and foster school improvement. These issues have been previously examined in the PISA questionnaires as domain-general context variables on the system level; domain-specific system-level context variables are also included in PISA 2022. While some information is collected through the PISA school questionnaire (SCQ), additional information can potentially be acquired by researchers and policymakers from other sources (e.g. system-level data, administrative records).

Detailed overview of PISA 2022 modules

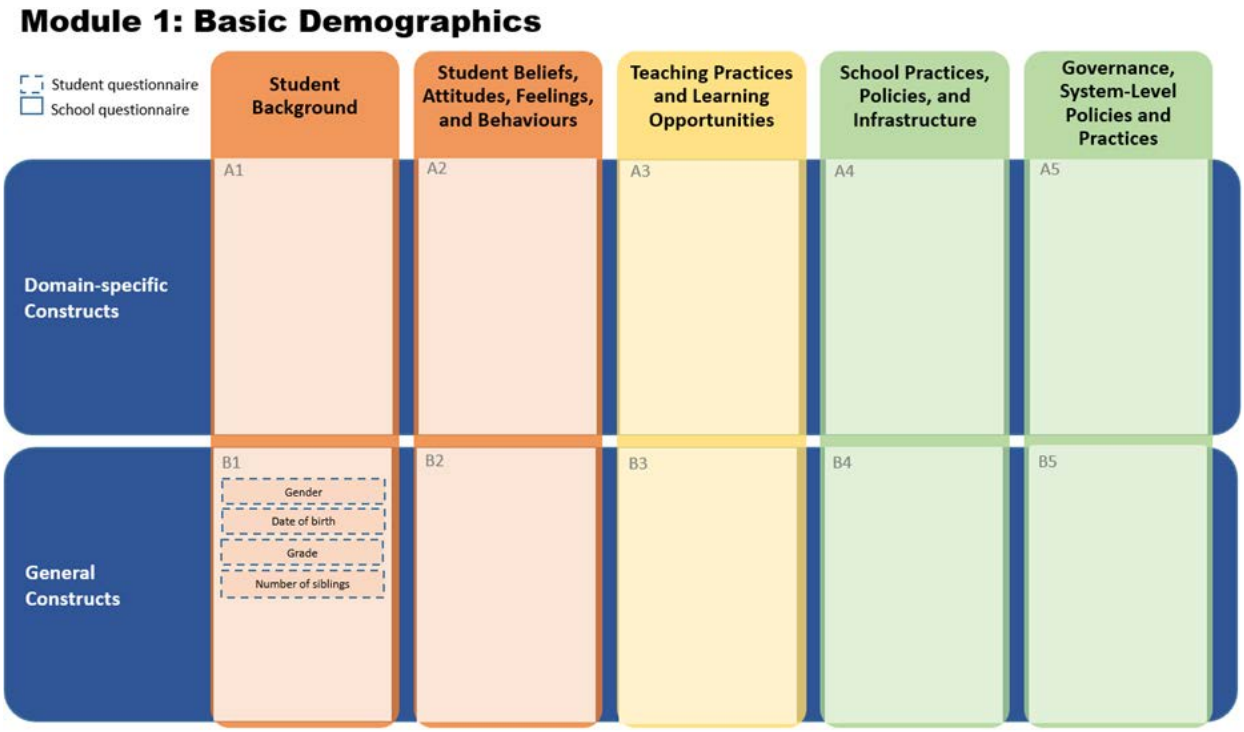
Basic demographics

PISA questionnaires have routinely included questions on students' gender and age, as well as their grade. These questions are included again in the STQ for the PISA 2022 MS.

The PISA 2022 FT explored updates to basic demographic questions on home composition to better reflect modern living realities in traditional as well as non-traditional homes and to establish a foundation for potential routing throughout the questionnaire based on, for instance, the students' number of parents or guardians. In order to maximize the strength of trendlines to data from previous cycles in light of the disruptions to education caused by the COVID-19 pandemic, these updated questions will not yet be included in the 2022 MS. This FT exploration marked, however, an important milestone towards a more modern description of students' homes in PISA in the mid to long term.

Figure 5.3. illustrates how all constructs in this module map onto the taxonomy.

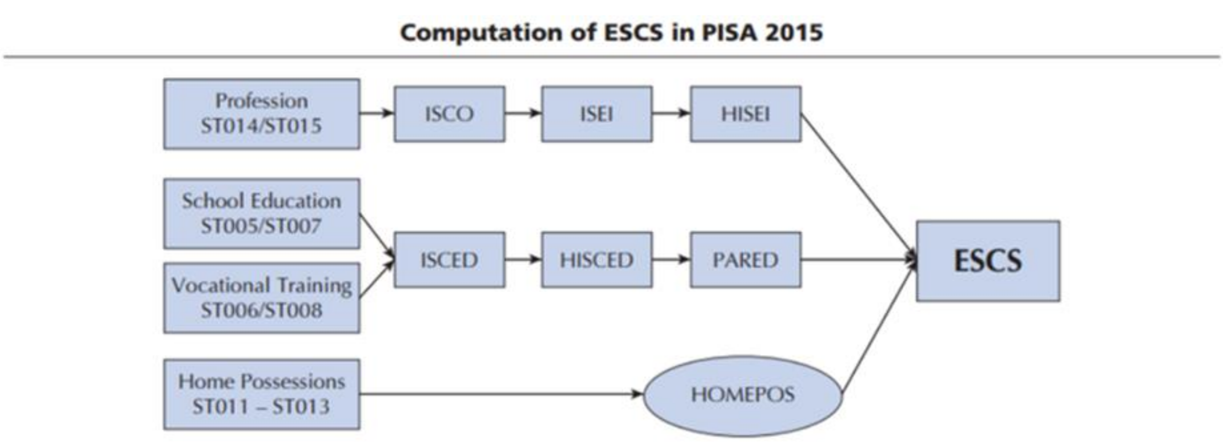
Figure 5.3. Constructs in basic demographics module



Economic, Social, and Cultural Status (ESCS)

Over the past seven PISA cycles, significant efforts have gone into the definition and operationalization of individual student background indicators, leading to the establishment of an integrated indicator for students' ESCS (Willms, 2006[28]; Lee, Zhang and Stankov, 2019[29]). Figure 5.4. displays how ESCS was created in the two most recent PISA cycles.

Figure 5.4. Computation of ESCS Index in PISA 2015 and 2018 (From PISA 2015 Technical Report)



Note: ISCO: International Standard Classification of Occupations; ISEI: occupational status of mother and father; HISEI: highest parental occupational status; ISCED: International Standard Classification of Education; HISCED: Highest education of parents (ISCED); PARED: Index for highest parental education in years of schooling; HOMEPOS: Index of home possessions (WLE); ESCS: Index of economic, social and cultural status.

The PISA ESCS index is considered internationally as a gold standard measure of socioeconomic status (SES) in LSAs (e.g. (Cowan, 2012[30])). To examine trends over time and comparisons with previous PISA data on the ESCS index, it is crucial to establish minimal stability in assessing the three components. While well established, the ESCS index has also been criticized in recent years (e.g. (Rutkowski and Rutkowski, 2013[31])), calling for revisions and extensions of the index.

Few changes have been made over the years to the measurement of ESCS in PISA, resulting in current approaches only partly accounting for students' living realities within and across the much more diverse PISA population. This issue becomes more pressing with the number of participating countries more than doubling over the past cycles. For instance, the current PISA ESCS questions continue to assume a traditional nuclear family with a mother and father and give little to no room for students to provide information about their families' income and education levels if they live in non-traditional constellations (e.g. multiple households, same-sex parents, multi-generational households, etc.).

While used for several cycles, issues remain with the International Standard Classification of Occupations (ISCO) and International Standard Classification of Education (ISCED) coding of parental educational levels and occupations (Kaplan and Kuger, 2016[32]) that pose challenges when making international comparisons on the respective questions. Recent findings from other studies further suggest that student reports on their parents' occupation tend to be very inaccurate, produce larger proportions of missing values, and that these questions take substantially more time to answer than other survey questions (e.g. (Tang, 2017[33])). Note that in previous PISA cycles, information about education levels among parents has been based on ISCED 1997 classifications; beginning with PISA 2022, the more recent ISCED 2011 classifications will be used. Table 5.6. summarizes how the updated ISCED 2011 levels correspond to the ISCED 1997 levels. More detailed information about the correspondence or concordance between levels in the ISCED 2011 classification and the earlier ISCED 1997 framework can be found in *the ISCED 2011 Operational Manual: Guidelines for Classifying National Educational Programmes and Related Qualifications* (UNESCO Institute for Statistics/OECD/Eurostat, 2015[34]).

Table 5.6. Correspondence between ISCED 2011 and ISCED 1997 Levels

ISCED 2011		ISCED 1997	
01	Early childhood educational development		--
02	Pre-primary education	0	Pre-primary education
1	Primary education	1	Primary education or first stage of basic education
2	Lower secondary education	2	Lower secondary education or second stage of basic education
3	Upper secondary education	3	(Upper) secondary education
4	Post-secondary non-tertiary education	4	Post-secondary non-tertiary education
5	Short-cycle tertiary education	5	First stage of tertiary education (not leading directly to an advanced research qualification) (5A, 5B)
6	Bachelor's or equivalent level		
7	Master's or equivalent level		
8	Doctoral or equivalent level	6	Second stage of tertiary education (leading to an advanced research qualification)

The PGB has expressed a desire to increase the benefits of participation in PISA for lower- and middle-income countries. The group has further expressed a need to incorporate questionnaire items that fully reflect the context found in those countries. The broadening of the PISA population to new countries and the widened socioeconomic divides in some countries call for a better approach of assessing the entire range from low to high socioeconomic circumstances. Having common questions between the PISA-D student and out-of-school youth questionnaires and the PISA STQ could be one way of achieving that linkage. The MS questionnaire will therefore include a broader set of home possession items than previous cycles as well as additional poverty indicators (e.g., food insecurity).

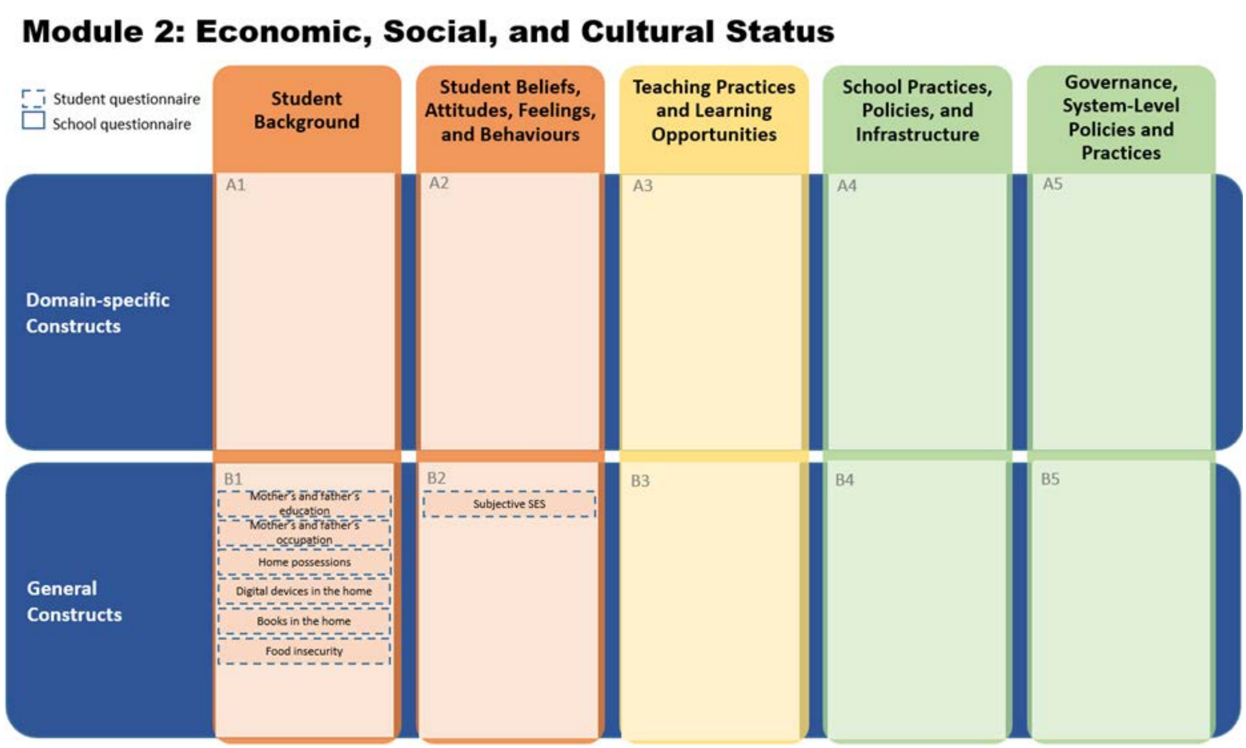
In addition to these updates, a range of more fundamental potential changes to the Index of ESCS were explored in the PISA 2022 FT, specifically replacing parent-focused with guardian-focused questions and replacing fill-in with multiple choice occupation questions. While these explorations resulted in findings that will help shape the mid- to long-term enhancement of the PISA questionnaires, the nature of the three main components of the Index of ESCS (Parental Occupational Prestige, Parental Education, Home Possessions) will remain unchanged in PISA 2022. Minimizing bigger changes to the index, while not ideal from an inclusiveness perspective, will allow keeping trend lines on ESCS with past cycles as strong as possible in efforts to contextualize student learning and disruptions thereof due to the COVID-19 pandemic.

Complementing the ESCS index, which will allow for strong trend comparisons, PISA 2022 will also measure food insecurity and subjective socio-economic status to gain a fuller perspective of students' backgrounds and potential obstacles to educational success they may be facing. Research demonstrates that the types of family SES variables necessary for student achievement differ depending on the country's overall developmental status; traditional measures of parental/guardian educational and occupational levels were more relevant to student achievement in richer countries than in poor countries (Lee and Borgonovi, 2022[35]).

Research on subjective SES suggests that student's subjective beliefs about their own and their family's status can be as important as objective SES measures in predicting important outcomes, ranging from achievement and overall future aspirations, to obesity and other health outcomes (e.g. (Citro, 1995[36]; Demakakos et al., 2008[37]; Goodman et al., 2001[38]; Lemeshow et al., 2008[39]; Quon and McGrath, 2014[40])).The most common approach for measuring subjective SES is Cantril's Self-Anchoring Ladder ((Cantril, 1965[41]); see (Levin and Currie, 2014[42]), for an adaptation for adolescents). It has been used in several variations, including extensions to subjective social status within the school community (Goodman et al., 2001[38]). A subjective SES measure will complement rather than replace the established ESCS indicator in PISA.

Figure 5.5. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.5. Constructs in ESCS module



Educational pathways and post-secondary aspirations

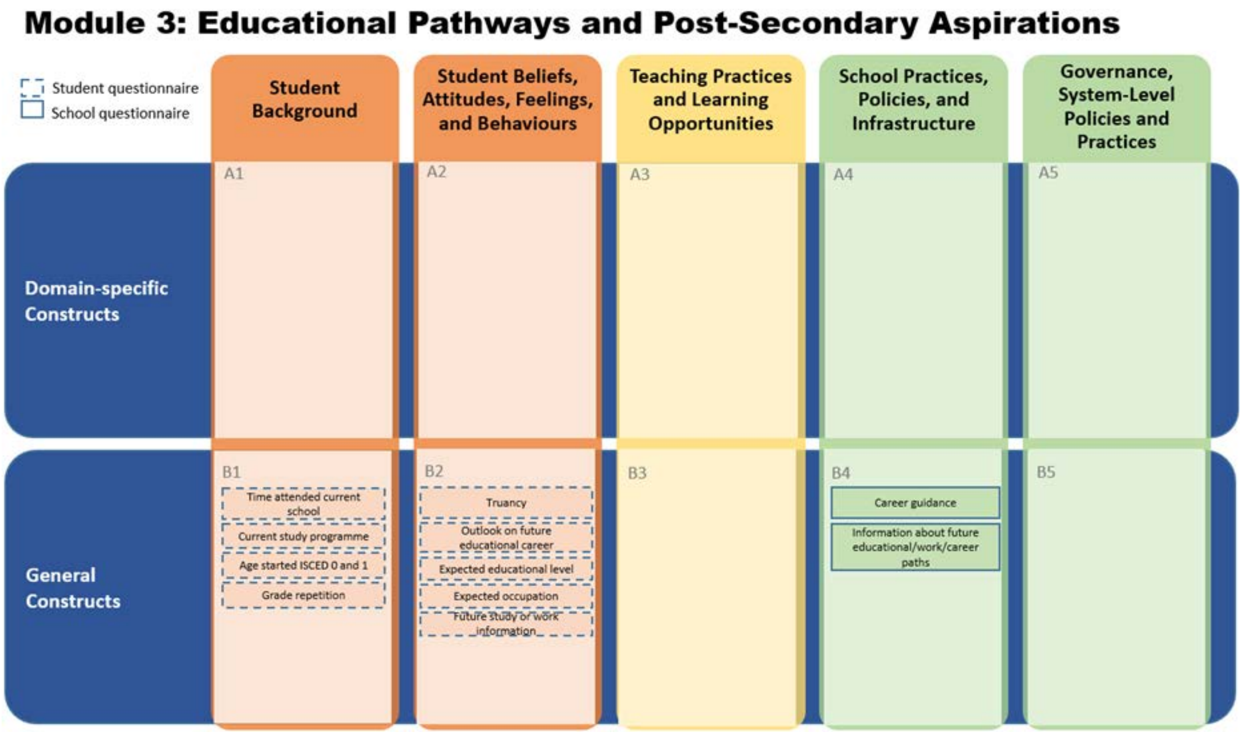
PISA gathers retrospective information about students' early years, educational pathways, and careers. Researchers and public debates in many countries have stressed the importance of early childhood education ((Blau and Currie, 2006[43]; Cunha et al., 2006[44]). PISA 2022 continues this tradition to capture essential information on primary and pre-primary education (bearing in mind that, for the most part, this would be solicited from 15-year-olds or their parents, which may pose validity challenges). Aspects of school attendance, such as truancy and grade repetition, are also captured as they have been found to significantly impact students' educational pathways. For example, school attendance problems have been linked to academic deficiencies including reduced educational performance, fewer literacy skills, and school dropout (Kearney et al., 2019[45]).

In addition to collecting data on students' early educational careers, previous PISA cycles have gathered prospective information about students' future educational pathways and preparation, and their occupational aspirations. While research in the United States has found that interpersonal relationships (e.g., peers, parents or guardians, teachers and staff who provide career guidance) play a significant role in shaping students' educational aspirations, cross-cultural research suggests that these influences may largely depend on the structural features of the educational systems in which they operate. For instance, peers and parents or guardians tend to influence educational aspirations in countries with undifferentiated secondary schooling, but this influence appears to be weaker in countries with more differentiated secondary education (Buchmann and Dalton, 2002[46]). It is possible that in differentiated systems, these effects may be indirect and mediated by early school-related decisions, such as track enrolment. An important factor to consider in understanding students' educational and work aspirations is the role that the school has in shaping these goals—for instance, through students' participation in the curriculum and activities offered by the school, and the provision of additional resources to explore educational and occupational pathways (e.g. (Beal and Crockett, 2010[47])).

Constructs measured in the STQ (e.g. attendance of ISCED 0-2; current study programme; history of students repeating a grade; missing, skipping, or arriving late to school; students' exposure to information about future studies or work; students' education and career expectations) and SCQ (e.g., school's support in providing information to students about future work and career paths) under this module are considered primarily as general constructs.

Figure 5.6. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.6. Constructs in educational pathways and post-secondary aspirations module



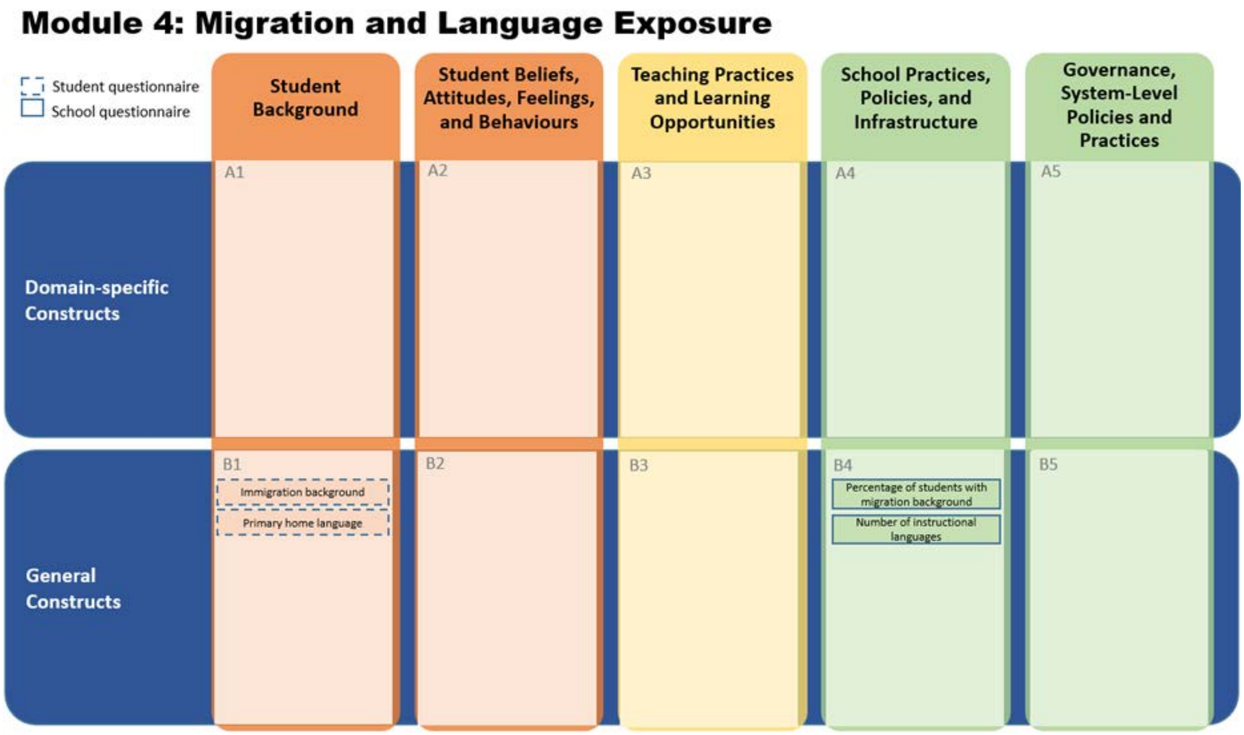
Migration and language exposure

Selected aspects of students' migration background and language exposure have been captured in previous PISA STQs as well as optional questionnaires (e.g., acculturation in the 2012 Educational Career Questionnaire). Immigration is currently a critical topic in many countries, particularly those with traditionally larger immigrant populations (e.g., the United States, Canada) as well as countries facing new challenges due to new populations of refugees (e.g., most central European countries) (Bansak, Hainmueller and Hangartner, 2016[48]; Wike, 2016[49]). Issues regarding the student's experience of a school climate that is accepting of diversity and multiculturalism are relevant to this module and overlap with content examined in the module on *School Culture and Climate* (Module 6).

STQ constructs in this module focus on assessing students' migration backgrounds (e.g., country of origin, age of arrival in country), and language backgrounds (e.g., primary language spoken at home). General constructs in the SCQ include the proportion of students with a migration background (e.g., immigrant or refugee status) and the number of languages taught at the school.

Figure 5.7. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.7. Constructs in migration and language exposure module



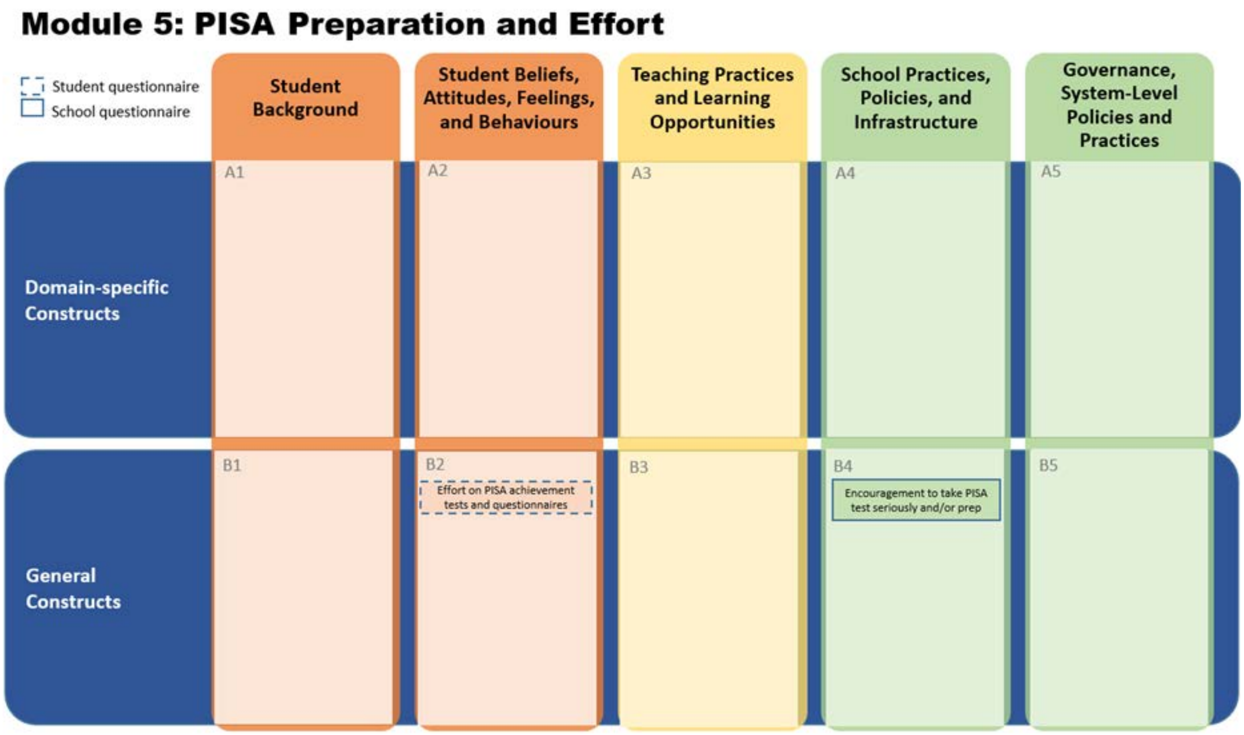
PISA preparation and effort

Several researchers have investigated questions of whether test-taker effort on low-stakes LSAs may impact achievement results or whether differential effort may play a role in explaining score differences between student groups or educational systems (e.g., (Debeer et al., 2014[50]; Eklöf, Pavešič and Grønmo, 2014[51]; Hopfenbeck and Kjærnsli, 2016[52]; Jerrim, 2015[53]; Penk, 2015[54]).

To inform educational policy regarding test-taker effort in PISA, this module covers students' subjective perceptions of how much effort they applied when answering the PISA test questions in mathematics, reading, or science, as well as filling out the STQ. Questions draw on the idea of the "effort thermometer" introduced in PISA 2003 (Butler and Adams, 2007[55]). To complement questions examining students' perceptions of effort, a new school question examines administrators' communication with teachers and parents or guardians about PISA and their encouragement of students to do their best during the PISA test. Furthermore, a project on developing and validating measures of engagement is currently under way as a part of the PISA Research, Development and Innovation (RDI) programme. The project explores, validates, and compares different approaches to developing measures of engagement, including experimentation with both innovative methods (e.g. using evidence on engagement defined in the process of item design) and more 'traditional' methods (e.g. situated self-reports, ex-post questionnaire items, indicators of performance decline and engaged time). The results of the project will become available in 2023.

Figure 5.8. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.8. Constructs in PISA preparation and effort module



School culture and climate

School climate, safety, and student well-being are important antecedents of academic achievement (Kutsyuruba, Klinger and Hussain, 2015[56]). School climate encompasses shared norms and values, the quality of relationships, and the general atmosphere of a school (Loukas, 2007[57])and is often described as the quality and character of school life that sets the tone for all the learning and teaching done in the school environment. An academic focus—that is, a consensus about the mission of the school and the value of education, shared by school leaders, staff, and parents or guardians—affects the norms in student peer groups and facilitates learning (LEE and SHUTE, 2010[26]; Opdenakker and Van Damme, 2000[58]; Rumberger and Palardy, 2005[59]). Research shows that positive school climate contributes to immediate student achievement and endures for years (Hoy, Hannum and Tschannen-Moran, 1998[60]). A positive school climate is associated with student's motivation to learn (Eccles et al., 1993[61]) and has been shown to moderate the impact of socioeconomic context on academic success (Astor, Benbenishty and Estrada, 2009[62]). Lastly, the relationships that a student encounters at all levels in school (including students' views of the quality of teacher-student support and student-student support) also impact student achievement (e.g., (Jia et al., 2009[63]; Lee, 2021[64]).

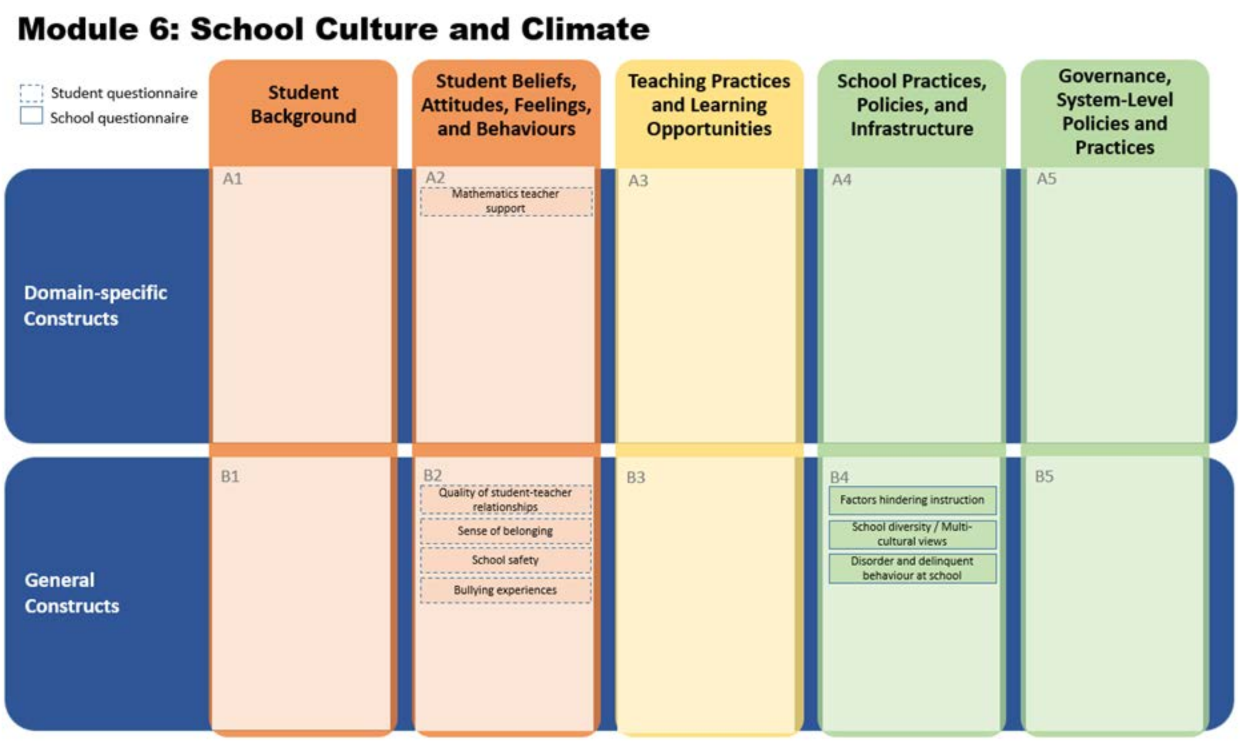
Closely related to school climate is the safety of the learning environment. An orderly, safe, and supportive learning atmosphere maximizes attendance and the use of learning time. By contrast, a learning environment characterized by disrespect, unruliness, bullying, victimisation, crime, or violence can act as a barrier to students' learning and distract from the school's overall mission and educational goals. In the area of safety, schools without supportive norms, structures, and relationships are more likely to experience violence and victimization, which is often associated with reduced academic achievement (Astor, Guerra and Van Acker, 2010[65]).

Learning in 21st century schools in many countries differs from traditional settings in terms of the diversity of the student population—for instance, diversity in racial/ethnic and cultural backgrounds, as well as diversity in individual student characteristics and diversity of thought. Experiences with diversity in the classroom may take the form of interpersonal interactions on campus, larger classroom discussions, or diversity-related coursework or workshops. In the United States context, researchers have found that several types of diversity experiences are associated with improvements in students' academic outcomes and cognitive development (e.g., development of critical thinking and problem-solving skills). Positive diversity experiences also play an important role in fostering students' social and emotional characteristics, such as tolerance, empathy, and curiosity (e.g. (Bowman, 2010[66]; Gurin et al., 2004[67]; Gurin et al., 2002[68]; Milem, Chang and Antonio, 2005[69]; Pettigrew and Tropp, 2006[70]).

General constructs in the PISA 2022 MS STQ include students' subjective perceptions as well as their values and beliefs about their in-school experiences. Measures are drawn from previously included constructs (e.g., sense of belonging, bullying experiences, school safety, and teacher support) as well as new constructs (e.g. quality of student-teacher relationships). Constructs in the SCQ include the school's efforts to promote school diversity/multi-cultural views, school climate-related factors hindering instruction, and disorder and delinquent behaviour at school. Questions in this module show some conceptual overlap with domain-specific questions in other modules (e.g., disciplinary climate in Module 16).

Figure 5.9. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.9. Constructs in school culture and climate module



Subject-specific beliefs, attitudes, feelings, and behaviours

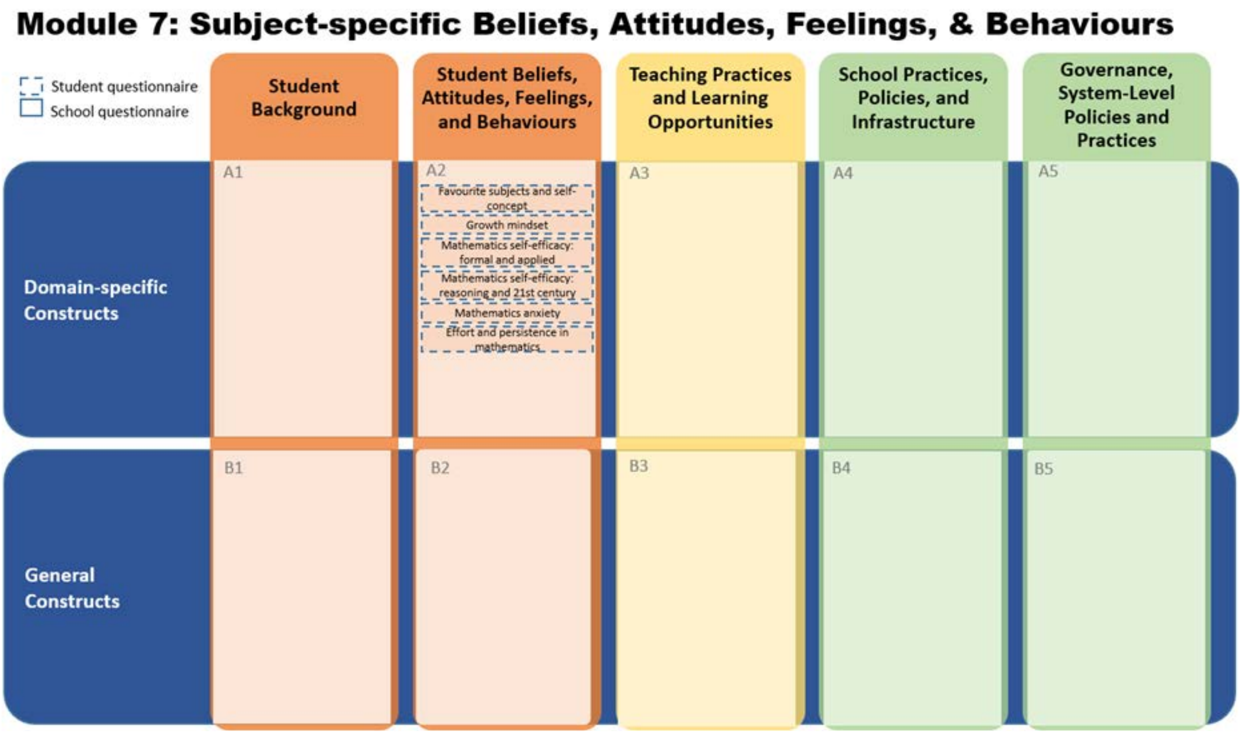
This module covers students' subjective perceptions as well as their values and beliefs, feelings and behaviours that are specific to mathematics, reading, and science. While a small set of key questions for each content-domain are included in the PISA 2022 MS, the focus of this module is on mathematics-related questions. Questions related to creative thinking are described in a separate module in this framework.

Questions related to all three domains include students' favourite subjects; whether students are motivated to achieve highly in mathematics, reading, and science; whether they think mathematics, reading, and science are easy for them; and the extent to which students think of skills in some subjects, as well as their general intelligence and creativity, as something malleable or largely robust to change (growth versus fixed mindset).

In addition, a combination of new mathematics-specific questions and questions retained from previous PISA cycles are recommended for this module. PISA 2012, for instance, assessed a number of mathematics-specific beliefs, attitudes, feelings, and behaviours. Four PISA 2012 scales (mathematics self-efficacy, mathematics anxiety, confidence in knowledge of mathematics concepts, and mathematics self-concept) were among the five constructs with consistently strongest correlational relationship with academic achievement in PISA 2012 (Lee and Stankov, 2018[71]). Based on these findings, measures for these constructs are also included in PISA 2022. Not all constructs, however, should be re-administrated without revisions and adjustments. On a trait level, mathematics self-efficacy, confidence, and self-concept are largely redundant (e.g. (Marsh et al., 2019[72])), a finding confirmed by PISA 2012 data when looking at joint relationships with achievement of these constructs. Mathematics self-efficacy and self-concept along with mathematics anxiety in PISA 2003 data formed a single second-order factor in the higher-order model to predict mathematics achievement (Lee and Stankov, 2013[73]). In both PISA 2012 and PISA 2003 data, self-efficacy showed better predictive validity for mathematics achievement than self-concept did (Lee, 2009[74]; Lee and Stankov, 2018[71]). For the PISA 2022 FT, the PISA 2012 self-efficacy scale was be retained and expanded by adding additional mathematics-reasoning related skills to the list of knowledge and skills. Self-efficacy was prioritized due to the concrete nature of the items that allow for clearer, more objective reporting than the agree/disagree type self-concept items used in PISA 2012. This difference in cross-cultural comparability of the two measures is reflected also in the finding that PISA 2012 self-efficacy showed consistently positive relationships with achievement both within and across countries, whereas relationships for self-concept were affected by the so-called “attitude-achievement-paradox” (Figure 5.25 in Section 5. of this framework). Rather than creating a second largely redundant scale focusing entirely on mathematics self-concept, this construct is operationalized for all three core PISA domains (mathematics, reading, and science) to allow for new insights based on potentially examining data as a profile across the three domains. Lastly, a new scale targeting students' invested effort and persistence in mathematics work (including homework) will provide actionable data for educators and policymakers that goes beyond the more subjective scales tapping into motivation in previous cycles.

Figure 5.10. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.10. Constructs in subject-specific beliefs, attitudes, feelings, & behaviours module



General social and emotional characteristics

Unlike the constructs listed above, constructs in this module are not primarily learning-related, but can be understood more broadly as characteristics indicative of student preparedness and social and emotional characteristics relevant to students' achievement in high school and throughout their lifetime. Two main framework approaches tend to be used to conceptualize social and emotional characteristics: one anchored to the personality psychology literature, which commonly refers to a "Big Five" taxonomy of personality traits (Abrahams et al., 2019[75]; Primi et al., 2021[76]); the other anchored to the social psychology literature, which focuses on cognitive constructs like motivations, beliefs, goals, interests, and values. PISA 2022 expands on these efforts by integrating the PISA framework with OECD's *Survey of Social and Emotional Skills* (SSES, (OECD, 2017[77])) to help policymakers and educators better link PISA data with other established frameworks and data sources. Based on the SSES framework, social and emotional characteristics can be defined as individual capacities that (a) are manifested in consistent patterns of thoughts, feelings, and behaviours, (b) can be developed through formal and informal learning experiences, and (c) influence important socioeconomic outcomes throughout individual's life. All general social and emotional characteristics measured in the PISA 2022 FT can be mapped onto the OECD SSES taxonomy (OECD, 2017[77]).

Task performance describes different aspects of students' conscientiousness and their striving for task performance, including setting high standards for themselves and working hard to meet them, fulfilling commitments and being reliable, being able to avoid distractions and focus attention on tasks, and persevering in the face of difficulty to complete tasks.

Emotional regulation covers different aspects of students' experienced range of emotions and their emotional regulation, including their ability to handle stress well, and regulate their temper, anger, and irritation in the face of frustrations.

Collaboration covers different aspects of students' approaches to collaboration, specifically their levels of agreeableness, including being kind and caring for others and valuing and investing in close relationships, building trust with others, as well as students' desire to value interconnections among people in general.

Open-mindedness covers different aspects of students' open-mindedness and openness to new experiences, including their desire to learn and approach situations with an inquisitive mindset, openness to different points of view and diversity, as well as enjoyment of generating novel ideas or visions.

Engaging with others covers different aspects of students' extraversion and their engagement with others, including their enjoyment of initiating and maintaining social connections, assertiveness in voicing their own views and exert social influence, as well as their tendency to approach daily life with energy, excitement, and spontaneity.

For the PISA 2022 MS, the following constructs are included that represent all five clusters of general social and emotional characteristics described above. Table 5.7. provides definitions for each construct that has partial item overlap between PISA 2022 and SSES.

Table 5.7. Definitions for constructs with partial item overlap between PISA 2022 and SSES

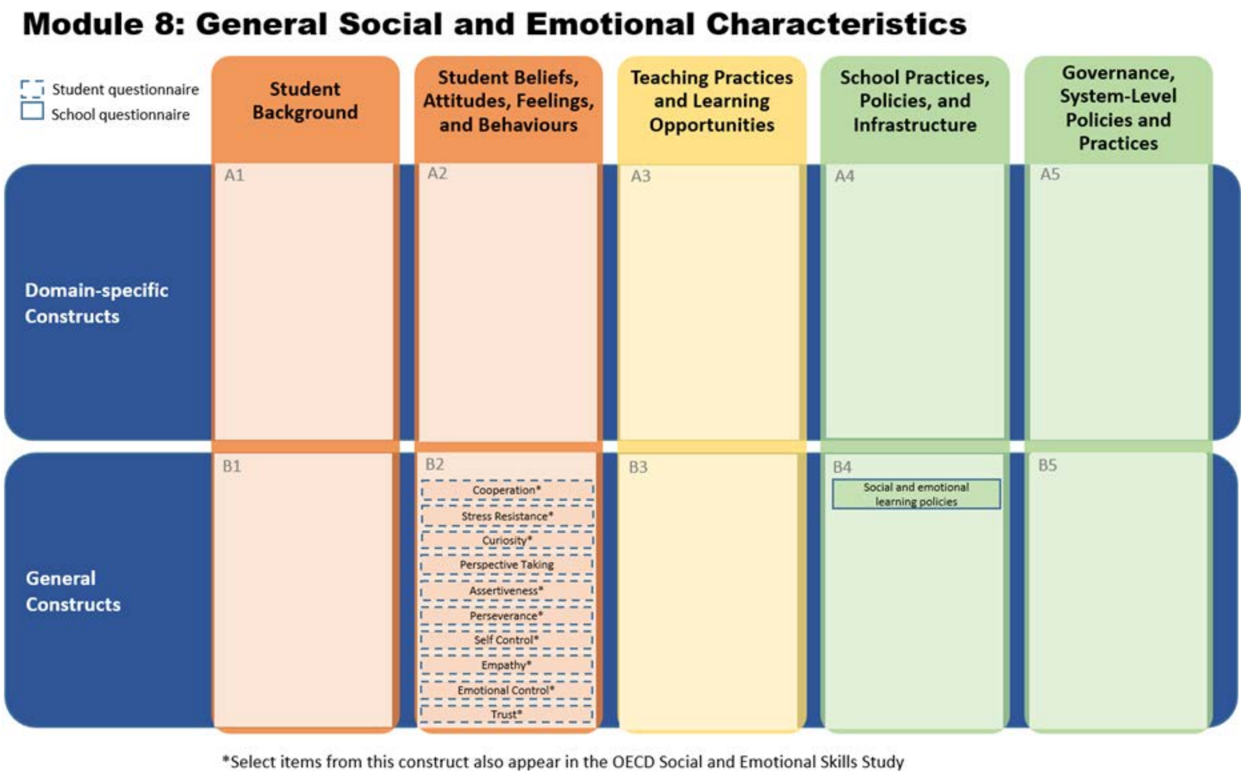
Big Five Domain	Skill	Description	Behavioural Examples
Task Performance (Conscientiousness)	Self Control	Able to avoid distractions and focus attention on the current task in order to achieve personal goals	Doesnt rush into things, is cautious and risk averse. Opposite: is prone to impulsive shopping or binge drinking
	Persistence (Perseverance)	Persevering in tasks and activities until they get done	Finishes homework projects or work once started Opposite: Gives up easily when confronted with obstacles/distractions
Emotional Regulation (Emotional Stability)	Stress Resistance	Effectiveness in modulating anxiety and able to calmly solve problems (is relaxed, handles stress well)	Is relaxed most of the time, performs well in high-pressure situations Opposite: worries about things, difficulties sleeping
	Emotional Control	Effective strategies for regulating temper, anger and irritation in the face of frustrations	Controls emotions in situations of conflict. Opposite: gets upset easily; is moody.
Collaboration (Agreeableness)	Empathy	Kindness and caring for others and their well-being that leads to valuing and investing in close relationships	Consoles a friend who is upset, sympathises with the homeless. Opposites: Tends to disregard other persons feelings.
	Trust	Assuming that others generally have good intentions and forgiving those who have done wrong.	Lends things to people, avoids being harsh or judgmental. Opposite: is suspicious of peoples intentions.
	Cooperation	Living in harmony with others and valuing interconnectedness among all people.	Finds it easy to get along with people, respects decisions made by a group. Opposite: Has a sharp tongue, is not prone to compromises.
Open-mindedness (Openness to Experience)	Curiosity	Interest in ideas and love of learning, understanding and intellectual exploration; and inquisitive mindset	Likes to read books, to travel to new destinations. Opposite: dislikes change, is not interested in exploring new products
Engagement with Others (Extraversion)	Assertiveness	Able to confidently voice opinions, needs, and feelings, and exert social influence.	Takes charge in a class or team. Opposite: waits for others to lead the way, keeps quite when disagree with others.

Note: Descriptions and behavioural examples for each skill based on OECD Survey of Social and Emotional Skills (OECD, 2017b). This table only shows the constructs for which partial item overlap between PISA and SSES was achieved.

Each construct will be measured with a set of items that partly stem directly from the SSES and partly are unique to PISA. Perseverance and Self-control (both representing the *Task performance* cluster), Stress resistance and Emotional control (representing the *Emotional regulation* cluster), Curiosity and Perspective taking (representing the openness cluster), Cooperation, Empathy, and Trust (representing the *Collaboration* cluster), and Assertiveness (representing the *Engaging with others* cluster). Please note, in addition to these constructs, the student well-being questionnaire (SWBQ, not described in this framework) includes a range of constructs related to each of the Big Five factors, and the Creative Thinking-focused module included in the core STQ captures additional facets of openness.

Figure 5.11. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.11. Constructs in general social and emotional characteristics module

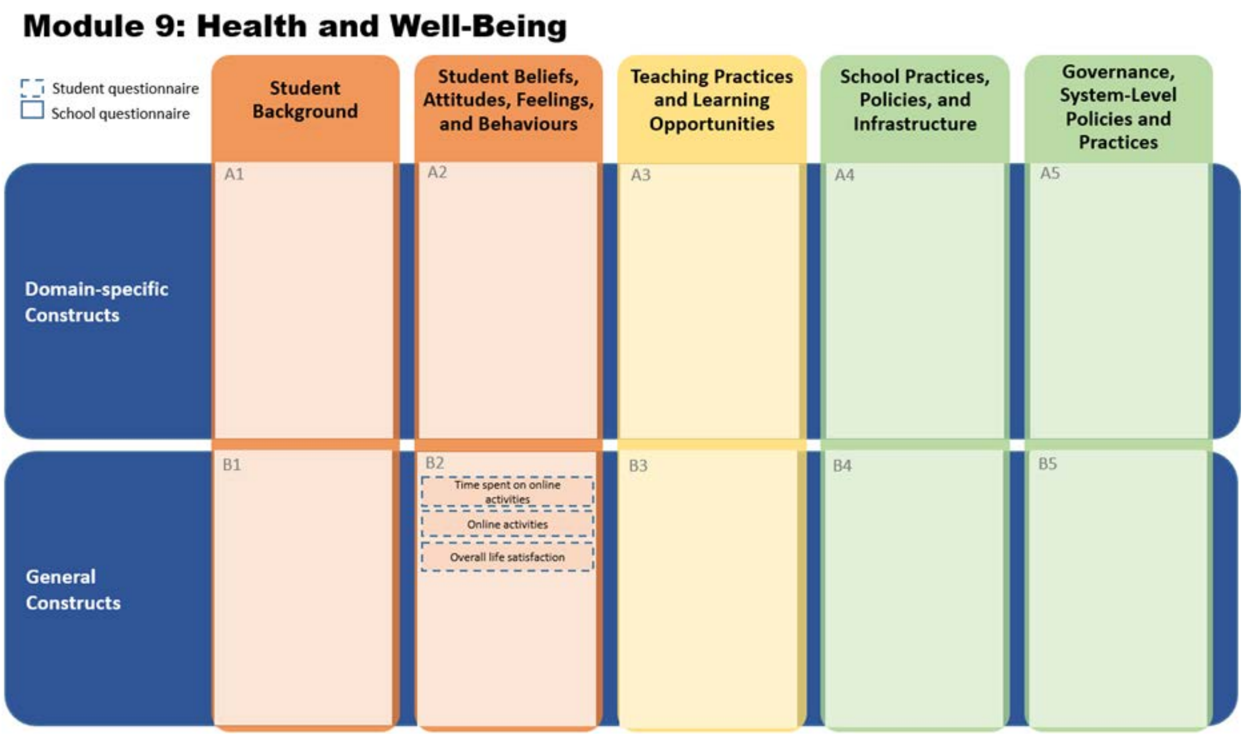


Health and well-being

PISA 2015 and 2018 started to include questions about health and well-being in the core STQ, and PISA 2018 offered an additional optional student well-being questionnaire (SWBQ) that gathered in-depth data on student well-being in participating countries. PISA 2022 carries these developments forward and includes, in addition to the optional SWBQ, a small module of health- and well-being related questions in the core STQ. Constructs for this module were selected to avoid any redundancies with the SWBQ and further prioritize well-being related questions that are important to capture student attitudes, feelings, and behaviour in all participating countries. These include students' overall life satisfaction, online activities, and potentially problematic online behaviours (e.g., extensive time spent on social networks and/or video games). The latter two constructs aim to understand the impact of online activities on students' health and well-being in light of the rapid growth of digital technology use across many aspects of daily life (e.g., socializing, communicating, and learning). Emerging research on adolescents and young adults—who are among the most active users of social media—suggests that digital technology use generally tends to have small, negative effects on well-being, and effects differ depending on the type and frequency of activities (Dienlin and Johannes, 2020[78]; Keles, McCrae and Grealish, 2019[79]; Schønning et al., 2020[80]). Questions included in other modules (e.g., school culture and climate, general social and emotional characteristics, out-of-school experiences, physical exercise) will yield additional data that informs constructs that may be conceptualized also as part of health and well-being (e.g., activities before and after school, sense of belonging, bullying, and student-teacher relationships).

Figure 5.12. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.12. Constructs in health and well-being module



Out-of-school experiences

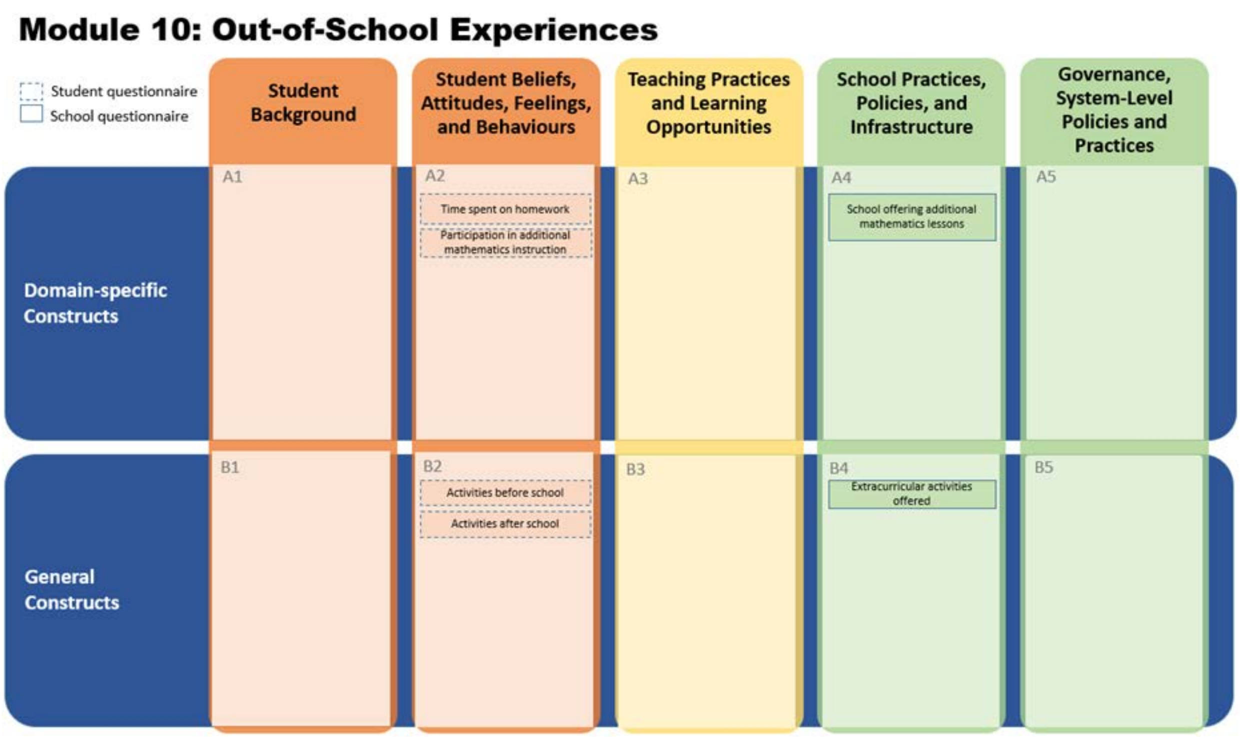
While classrooms serve as important settings for students' engagement in opportunities to learn, student engagement and learning also occur through formal and informal opportunities to learn outside of school. In the 2015 and 2018 questionnaire frameworks, students' out-of-school experiences focused on domain-specific indicators. The PISA 2022 framework takes a broader view on out-of-school experiences including both academic and non-academic experiences that may fall into several of the defined educational policy areas, including student attitudes, feelings, and behaviours and school practices, policies, and infrastructure.

How students spend their time outside of school, and the extent to which they engage in learning-related activities outside of school (e.g., tutoring, extracurricular activities, homework, mathematics-related activities), are important for understanding student achievement. Studies have shown that students' time use outside of school relates to mathematics achievement across several countries (Fuligni and Stevenson, 1995[81]), and engagement in extracurricular activities is associated with lower dropout rates for at-risk students, improved grade point averages, and higher educational aspirations (Broh, 2002[82]; Mahoney and Cairns, 1997[83]). Out-of-school activities can also provide important opportunities to learn, whereby students can apply subject-related content and skills that have been emphasized in class to novel situations. This may be especially true for populations that have less exposure to formal education, as well as countries where structured out-of-school learning activities are prevalent (e.g. after-school tutoring to supplement and enhance in-school learning).

Domain-specific constructs in the STQ include students' participation in additional mathematics lessons outside of school and tutoring, and time spent on mathematics homework. Domain-specific constructs in the SCQ include administrators' reports of the school offering additional lessons in mathematics. General constructs in the STQ include students' activities before and after school (including physical activities or working for pay); general constructs in the SCQ include extracurricular activities offered by the school.

Figure 5.13. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.13. Constructs in Out-of-school experiences module



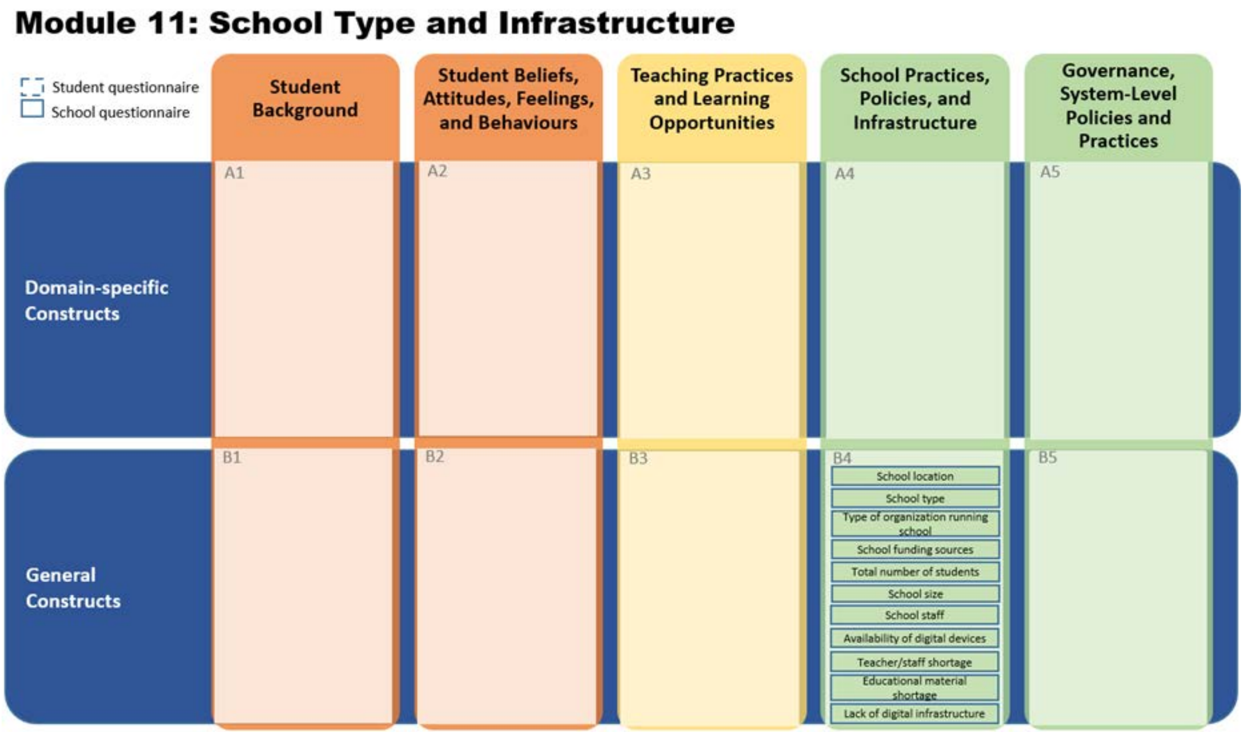
School type and infrastructure

This module examines aggregate school-level characteristics of the students' learning environment (e.g., location, type, and size of the school) and school risk factors that may hinder student learning and achievement as they relate to the physical set-up of the school, such as deficiencies in school resources and infrastructure. The quality of a school's infrastructure, and the quality and accessibility of digital educational resources (e.g., computers and other digital technology, internet access) may facilitate or hinder the learning environment's positive impact, and in turn, influence achievement.

Conceptually, this module overlaps with other modules measuring the overall characteristics of the school and school population, including those capturing school culture and climate (Module 6), organisation of student learning at school (Module 14); assessment, evaluation, and accountability (Module 18); and school autonomy (Module 13). General constructs in the SCQ include school size (teachers, students, and non-teaching staff), school type and the type of organisation running the school, school location, availability of digital technology, and lack of physical and digital infrastructures.

Figure 5.14. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.14. Constructs in school type and infrastructure module



Selection and enrolment

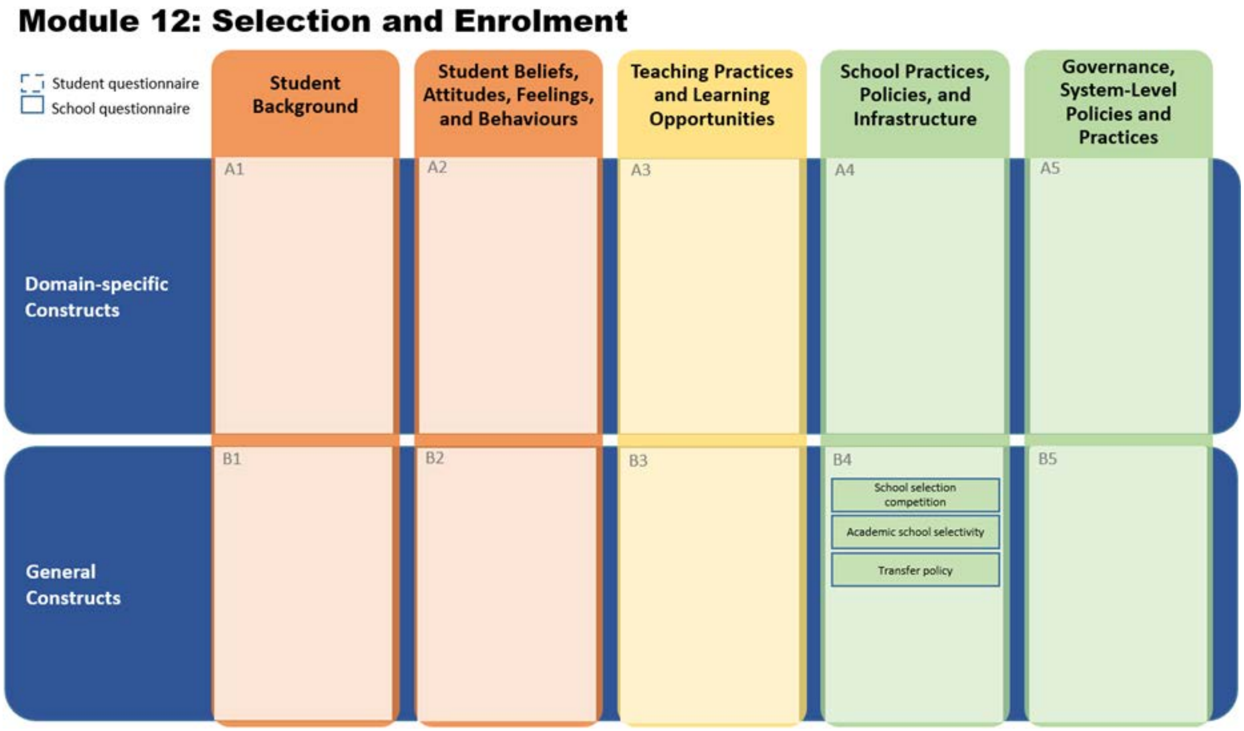
School principals and administrators play a key role in school management and policy, as they are often seen as the primary agents of change to improve student achievement in their schools. They can shape teachers' professional development, define the school's overall mission and educational goals, ensure that instructional practices and policies within and across subjects are directed towards achieving these goals, suggest modifications to improve teaching practices, and help solve problems that may arise within the classroom or among teachers.

The way in which students are channelled into educational pathways, schools, tracks, or courses (also known as stratification, streaming, or tracking) is a core issue of educational governance and is an important aspect of school organisation and policy. For instance, highly selective schools provide a learning environment that may differ from the environment offered by schools that are more comprehensive. Some longitudinal studies have demonstrated grade retention harms individual careers and outcomes (e.g., (Griffith et al., 2010[84]; Ou and Reynolds, 2010[85]), as well as student behaviour and well-being (e.g., (Crothers et al., 2010[86])), while other research finds positive effects (Marsh et al., 2017[87]). Greene and Winters (2009[88]) showed that once a test-based retention policy has been installed, those who were exempted from the policy did worse. Additionally, Babcock and Bedard (2011[89]) showed that a large number of students being retained could have a positive effect on the cohort (i.e., all students, including those who are promoted). Kloosterman and De Graaf (2010[90]) argued that in highly tracked systems, such as in some European countries, grade repetition might serve as a preferred alternative to moving into a lower track. The authors found evidence that this strategy is preferred for students with higher SES. Thus, changing grade repetition policies might be a viable option regarding low-cost interventions (Binder, 2009[91]).

General constructs in the SCQ include the school's selection competition, academic selectivity, and student transfer policies.

Figure 5.15. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.15. Constructs in selection and enrolment module

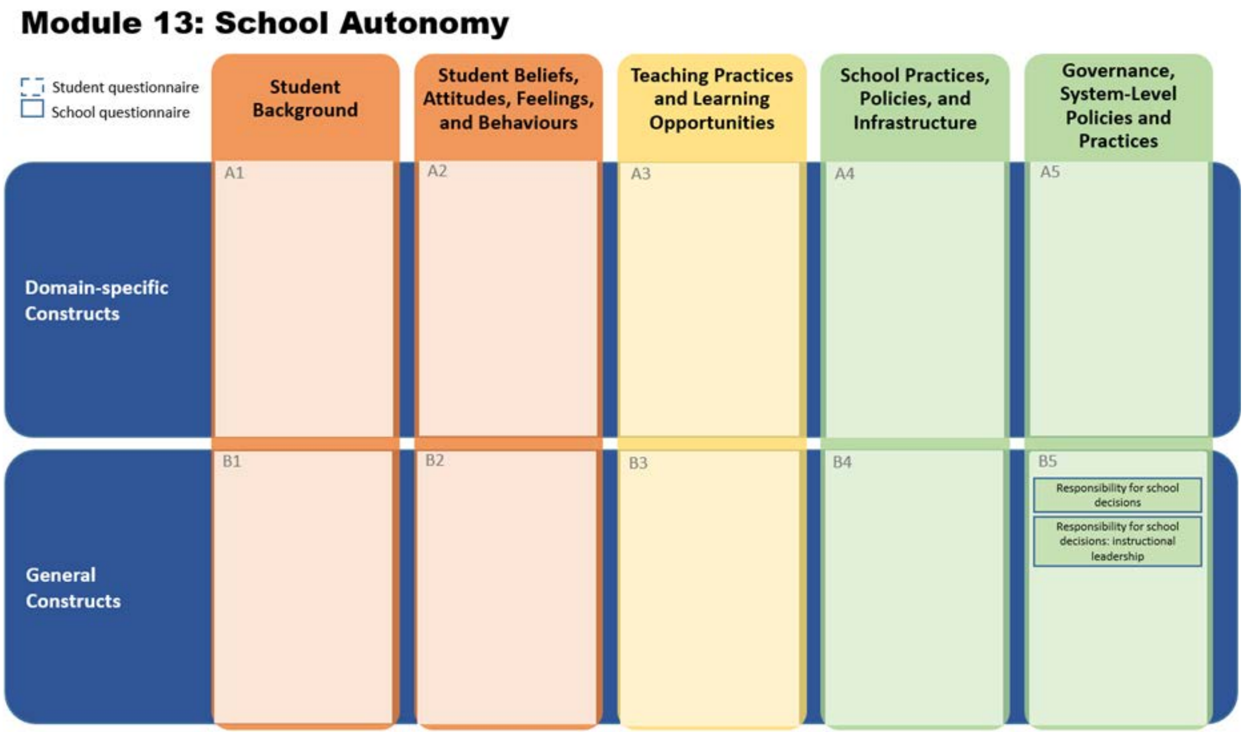


School autonomy

Education systems have been classified by the amount of control or local autonomy that is given to schools (i.e., the school board, staff, and school leaders) versus governing bodies at the local, regional, or national level when decisions on admission, curriculum, allocation of resources, and personnel must be made. These indicators have been previously included in the PISA 2012 SCQ and are revisited in 2022. General constructs in the SCQ include administrators' reports of the primary responsibility for school decision making and the role of the school management team in providing instructional leadership to teachers.

Figure 5.16. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.16. Constructs in school autonomy module



Organisation of student learning at school

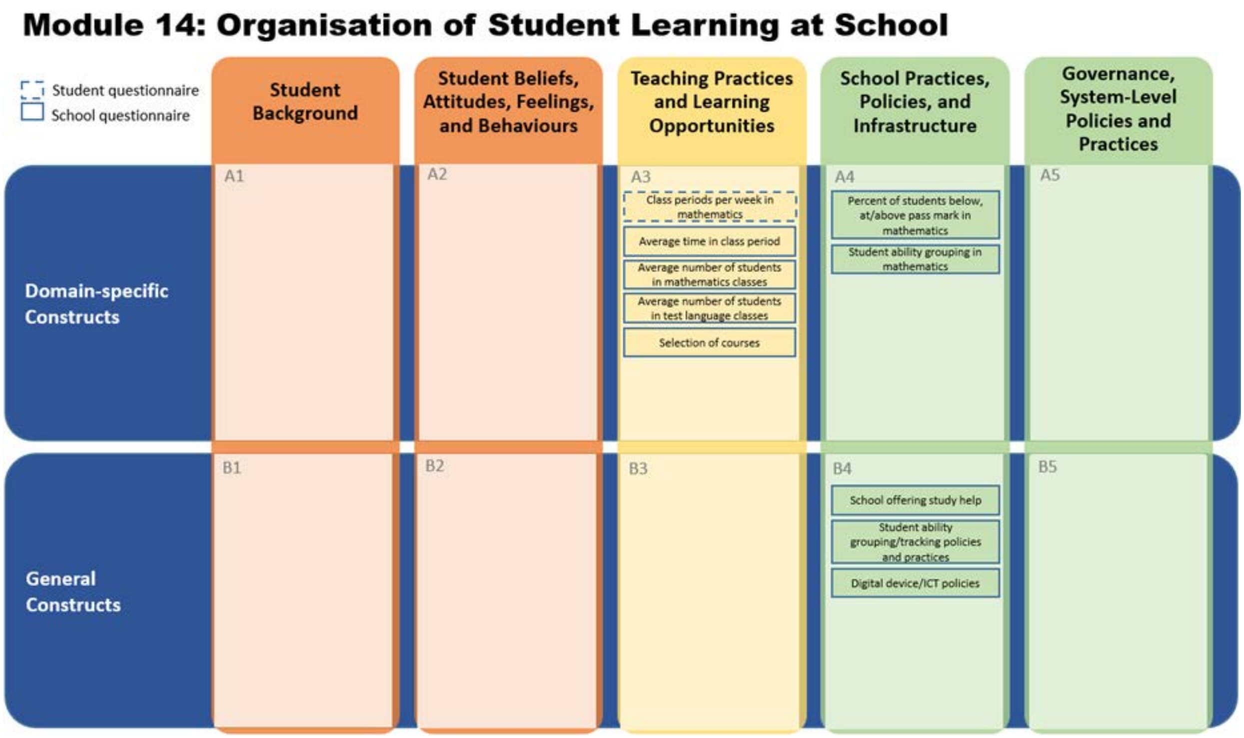
Large portions of students' educational experiences tend to occur at school in the classroom environment. During time spent in the classroom, students are exposed to subject content, curriculum materials, instructional strategies, skills, and a diversity of backgrounds and perspectives contributing to overall climate. Learning time and the intended curriculum content in school have been found to be closely related to student outcomes (e.g., (Abedi, 2006[15]; Cogan, Schmidt and Guo, 2018[92]; Scherff and Piazza, 2008[93]; Schmidt, 2009[17])). Overall students' learning time and achievement are correlated as the time allowed for learning constrains students' opportunities to learn, though there are large differences within countries, across countries, and among different groups of students and schools (Ghuman and Lloyd, 2010[94]; OECD, 2011[95]). A generally positive relationship has been replicated in international comparative research (e.g. (OECD, 2011[95]; Martin, Mullis and Foy, 2008[96]; Schmidt, 2001[16]; Schmidt and Burroughs, 2016[97]; Schmidt et al., 2015[98]).

Related to learning time is the way intended learning content is designed, structured, and communicated during that time in school. Understanding how a school curriculum functions requires a consideration of how it is organised and how students gain access to it. For example, a school's curriculum can be understood by examining what coursework is required and optional; whether students are tracked or grouped by achievement; and what standards are used to develop subject content. Curriculum may vary largely across tracks, grades, schools, and countries (Schmidt, 2001[16]; Martin, Mullis and Foy, 2008[96]). Overall, there may be variations between the curriculum designed at the system level, the curriculum communicated by the teacher or in the textbook, and the curriculum as understood by students and their parents.

A domain-specific construct included in the STQ captures students' mathematics class periods per week. Domain-specific constructs in the SCQ capture administrators' reports of the average time in a class period, the average number of students in these classes, percentages of students below/above the pass mark, student ability grouping in mathematics, the school offering study help, tracking policies, digital device policies, and selection of courses. This module complements Modules 15 (*Exposure to Mathematics Content*) and Module 16 (*Mathematics Teacher Behaviours*) in mapping out a broad view of students' OTL at school.

Figure 5.17. below illustrates how all proposed constructs in this module map on the taxonomy.

Figure 5.17. Constructs in organisation of student learning at school module



Exposure to mathematics content

This module focuses on one key aspect of the broader OTL constructs, specifically students' exposure to relevant mathematics content. In conjunction with the modules on Organisation of Student Learning at School (Module 14) and Mathematics Teacher Behaviours (Module 16), this module focuses on the first three types of OTL-related variables described by Stevens (Stevens, 1993[99]):

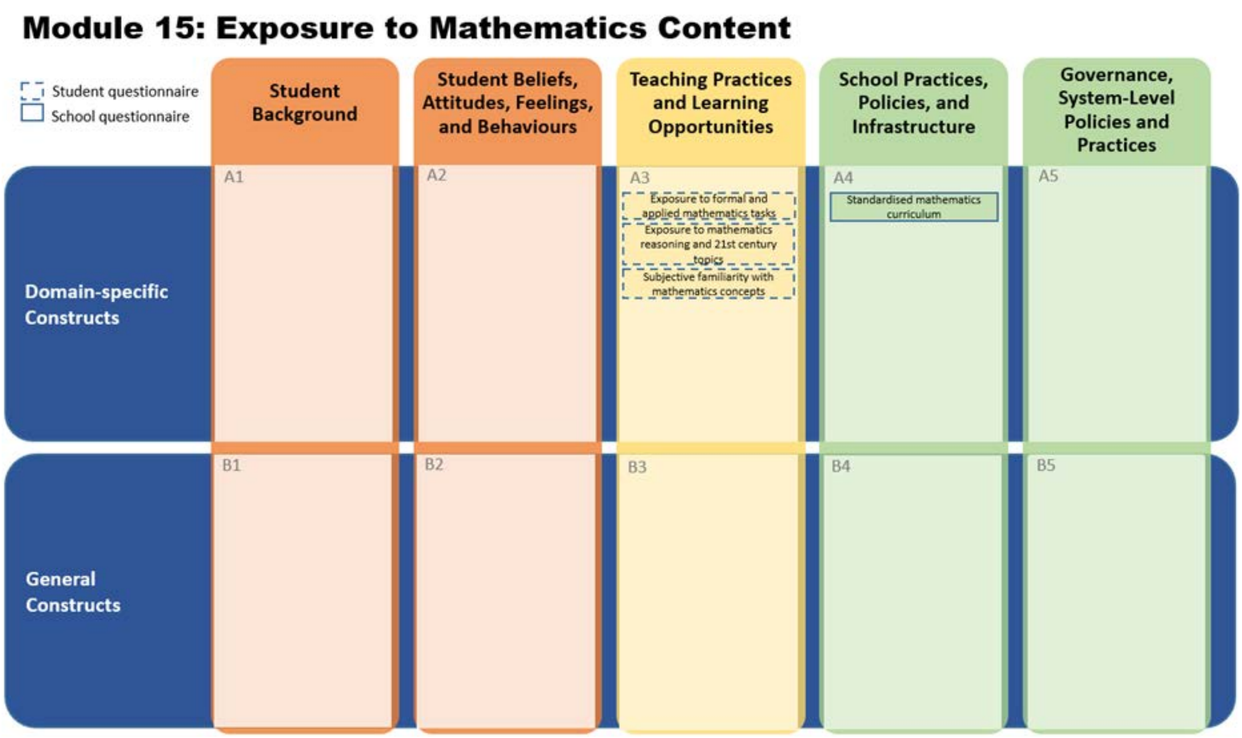
- *Content coverage variables* that measure whether students learn the content covered in the curriculum for a particular grade level or subject;
- *Content exposure variables* that consider the time allowed for and devoted to instruction and the depth of teaching provided;
- *Content emphasis variables* that consider which topics within the curriculum are selected for emphasis and which students are selected to receive instruction emphasizing either lower-order skills (i.e., rote memorization) or higher-order skills (i.e., critical problem solving); and
- *Quality of instructional delivery variables* that measure how classroom teaching practices (i.e., presentation of lessons) affect students' academic performance.

PISA 2012 aimed to capture domain-specific (mathematics) OTL profiles in the STQ through the presentation of tasks reflecting mathematical abilities and content categories outlined in the PISA mathematics framework. Students were asked to judge whether and how often they had seen similar tasks in their mathematics lessons; thus, OTL measures in PISA 2012 (experience with pure and applied math tasks, experience with problem types in mathematics, and familiarity with mathematics concepts) were mainly concerned with aspects of content coverage and exposure.

One specific area for new development in PISA 2022 was around students' OTL with regard to mathematics reasoning skills. The goal of PISA 2022 is to measure in-school OTL (i.e., content coverage and exposure) at the school and country level in a way that allows for a clearer differentiation between types of mathematics problems and mathematics content—for instance, country-level differences in opportunities to learn formal mathematical modelling or applied mathematics problems. Domain-specific constructs in the STQ include students' exposure to different types of mathematics content (formal and applied mathematics tasks), as well as their exposure to mathematics reasoning and 21st century skills related to mathematics and their subjective familiarity with mathematics concepts. A domain-specific construct pertaining to the standardisation of the school's mathematics curriculum is also included in the SCQ.

Figure 5.18. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.18. Constructs in exposure to mathematics content module



Mathematics teacher behaviours

How student learning is organised (Module 14) and what content is being taught (Module 15) are conceptually distinct from constructs that capture teaching practices and behaviours (instructional quality), in that teaching practices and behaviours can serve as vehicles through which different levels of content coverage and exposure may occur. What teachers do has the strongest direct school-based influence on student learning outcomes (Hattie, 2009[100]). Effective instruction is rooted in part in the repertoire of practices through which teachers facilitate students' thinking and understanding of subject content and concepts. Previous research has shown that proximal variables, such as classroom characteristics and teaching and learning practices, are more closely associated with student achievement than distal variables measured at the school- and system-level (e.g. (Hattie, 2009[100]; Slavin and Lake, 2008[101]; Wang, Haertel and Walberg, 1993[102]).

Though understood differently across the field, there is general agreement that teachers' instructional practices, or instructional quality, is a multidimensional concept (e.g., (Fauth et al., 2014[103]; Kane and Cantrell, 2010[104])). The 2018 OECD Teaching and Learning International Survey (TALIS) framework identifies the following dimensions of teaching practices as having an influence on student achievement:

- *Classroom management,* or the actions taken by teachers to ensure order and effective use of time during lessons (van Tartwijk and Hammerness, 2011[105]);
- *Teacher support,* such as providing extra help when needed, listening to and respecting students' ideas and questions, caring about and encouraging students, and providing emotional support to them ((Klieme, Pauli and Reusser, 2009[106]; Lee, 2021[64]);
- *Clarity of instruction,* that is, teachers' clear and comprehensive instruction and learning goals, connection of old and new topics, and summarization of lessons ((Hospel and Galand, 2016[107]; Kane and Cantrell, 2010[104]; Seidel, Rimmele and Prenzel, 2005[108]);
- *Cognitive activation*, or the use of instructional activities involving evaluation, integration, and knowledge application in the context of problem solving, through which students engage in knowledge construction and higher order thinking (Lipowsky et al., 2009[109]); and
- *Instructional assessment and feedback*, more specifically, the provision of constructive feedback through formative and summative assessment (Hattie and Timperley, 2007[110]; Kyriakides and Creemers, 2008[111]; Scheerens, 2016[112]) or homework (Cooper, Robinson and Patall, 2006[113]).

Previous TALIS main study results from 2008 found that in 23 countries, participation in professional development and teaching high-ability classes raised the frequency of teachers implementing practices to improve clarity of instruction, teacher support, and cognitive activation (via enhanced activities). It is important to note that while effective pedagogical practices overlap across subjects and student populations, some practices may vary by specific subjects and populations. For instance, TALIS data indicate that mathematics and science teachers reported less student-oriented instructional support and less frequent use of enhanced activities compared to teachers who taught other subjects (OECD, 2009[114]).

While TALIS has focused on measurement of general teaching practices, PISA 2022 complements these efforts by measuring closely aligned constructs that are domain-specific (i.e., mathematics focused), as has been done in previous cycles.

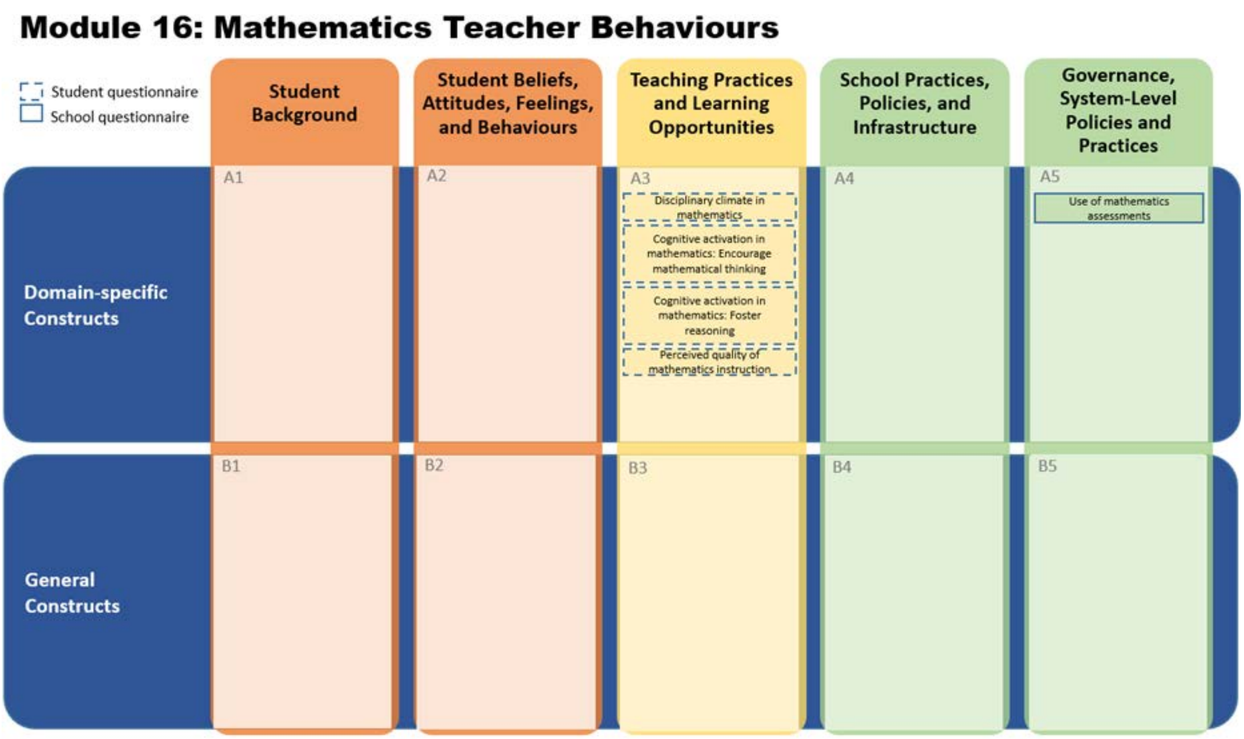
- *Disciplinary climate in mathematics* examines disciplinary issues that hinder mathematics learning in the classroom, complementing the TALIS dimension of *classroom management*;
- *Mathematics teacher support* covered in Module 6 (School Culture and Climate) is conceptually aligned with the dimension of *teacher support*;
- *Cognitive activation in mathematics* is conceptually similar to the dimension of *cognitive activation*, however, PISA is focused specifically on the extent to which teachers encourage mathematical thinking and reasoning skills as highlighted in the PISA 2022 mathematics framework; and
- *Use of mathematics assessments* is conceptually aligned to the dimension of *instructional assessment and feedback*, providing additional information about instructional assessment and feedback in mathematics.

Aspects of classroom disciplinary climate, teacher support, cognitive activation, and teacher behaviour (student-oriented) were measured in PISA 2012. Previous research indicates that several of the dimensions defined above correlate with students' mathematics outcomes (e.g., (Lee, 2021[64])). For instance, the international PISA 2003 report found that disciplinary climate in the mathematics classroom was strongly associated with mathematical literacy, while other variables (e.g., class size, mathematical activities offered at the school level, avoidance of ability grouping) had no substantial relationship once socioeconomic status was accounted for (OECD, 2004[115]). The PISA 2012 data also showed strong predictive validity of disciplinary climate for students' mathematics achievement (Lee and Stankov, 2018[71]). Additionally, teacher support has been found to be positively linked to students' interest in mathematics after accounting for socioeconomic status (Vieluf et al., 2012[116]). Finally, cognitive activation in the form of providing learners opportunities to develop and practice mathematical competencies have been broadly discussed in mathematics education (e.g. (Blum and Leiss, 2007[117])).

Addressing teacher and teaching-related factors in PISA is a challenge, because sampling is by age rather than by grade or class. Nevertheless, aggregated student data and the optional teacher questionnaire can be utilized to describe several aspects of teacher background and practices, and the learning environment offered in classrooms.

Figure 5.19. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.19. Constructs in mathematics teacher behaviours module



Teacher qualification, training, and professional development

OECD's annual International Summit on the Teaching Profession (ISTP; (Schleicher, 2014[118])) has exemplified the continuously growing focus on teacher-related policies for improving the quality of teachers, teaching, and learning. In addition to teacher's professional behaviour (e.g., interactions with students in the classroom and with their parents or guardians), the composition of the teaching force in terms of age and educational level, their initial education and qualifications, their individual beliefs and competencies, as well as professional practices on the school level (e.g., professional development, interactions with parents) have been topics of educational policy discussions.

A number of studies have demonstrated a clear influence of teacher-related factors on student learning and outcomes (e.g., (Schmidt et al., 2016[119])). Several studies and reviews show positive relationships between teachers' initial education and their teaching effectiveness (e.g., (Boyd et al., 2009[120]; Darling-Hammond et al., 2005[121])). Research has shown that when teachers have opportunities to expand and develop their teaching practices and their knowledge of instructional approaches, they are more likely to provide a broader range of learning opportunities for students and be more effective in improving students' learning outcomes (Harris, 2002[122]; Rankin-Erickson and Pressley, 2000[123]).

General constructs in the SCQ include administrators' reports of teacher qualifications, and in-house professional development opportunities. Domain-specific constructs in the SCQ include mathematics teacher qualifications and mathematics in-house professional development opportunities.

Figure 5.20. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.20. Constructs in teacher qualification, training, and professional development module

Assessment, evaluation and accountability

Assessing students and evaluating schools are common practices in most countries (Ozga, 2012[124]). Since the 1980s policy instruments, such as performance standards, standard-based assessment, annual reports on student progress, and school inspectorates, have been promoted and implemented across continents. Reporting and sharing data from assessments and evaluations with different stakeholders provides multiple opportunities for monitoring, feedback, and improvement. In recent years, there has been a growing interest in the use of assessment and evaluation results through feedback to students, parents or guardians, teachers, and schools as one of the most powerful tools for quality management and improvement (OECD, 2010, p. 76[125]). In addition, formative assessment, also known as assessment for learning, has been one of the dominant movements (Baird et al., 2014[126]; Black, 2015[127]; Hattie, 2009[100]). Accountability systems based on these instruments are increasingly common in OECD countries (Rosenkvist, 2010[128]; Scheerens, 2002, p. 36[129]).

Prior PISA cycles have covered aspects of assessment, evaluation, and accountability in the SCQ by identifying a variety of purposes for the assessment of students. School administrators have been asked whether they use test results to make comparisons with other schools at the district or national level, as well as to improve teacher instruction (e.g., by asking students for written feedback on lessons, teachers, or resources). However, extant research indicates that there are very few low-income countries that have a national assessment system in place that can track learning in a standardized manner to provide feedback into education policies and programs (Birdsall, Bruns and Madan, 2016[130])

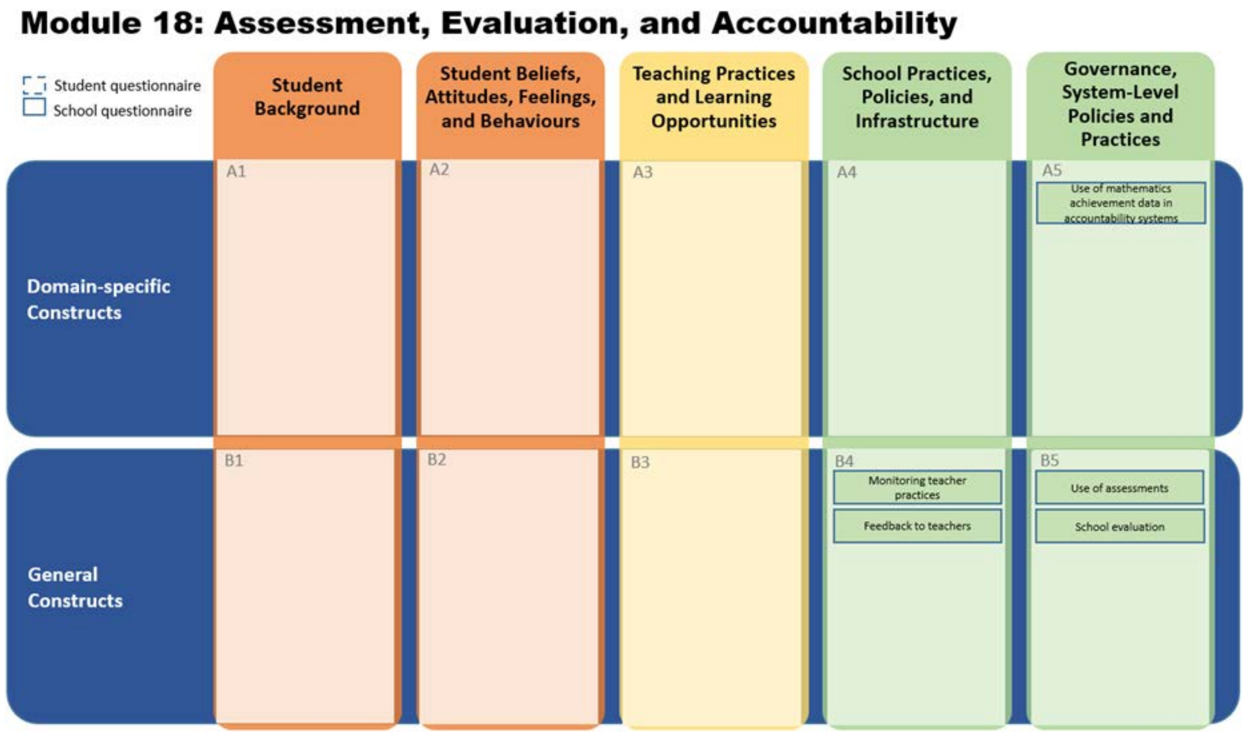
The evaluation of schools is used as a means of assuring transparency; making judgments and decisions about systems, programs, educational resources and processes; and guiding overall school development (Faubert, 2009[131]), and evaluation criteria may be defined and applied from the viewpoints of different stakeholders (Sanders and Davidson, 2003[132]). Evaluation can either be external (i.e., the process is controlled and headed by an external body and the school does not define the areas that are judged) or internal (i.e., the process is controlled by the school itself and the school defines the areas that are judged) (Berkenmeyer and Müller, 2010[133]). The evaluation may be conducted by members of the school, or by persons/institutions commissioned by the school. Different evaluation practices generally coexist and benefit from each other (Ryan, Chandler and Samuels, 2007[134]). For instance, external evaluation can expand the scope of internal evaluation and also validate results and implement standard or goals. Additionally, internal evaluation can improve the interpretation and increase the utilization of external evaluation results. However, improvement of schools seems to be more likely when an internal evaluation is applied, compared to external evaluation. Thus, processes and outcomes of evaluation may differ between internal and external evaluation. Moreover, country and school-specific context factors may influence the implementation of evaluations as well as the conclusions and impact for schools. In many countries, individual evaluation of teachers and principals, separate from school-wide evaluation, is also common (Faubert, 2009[131]; Santiago and Benavides, 2009[135]). One study looked at 12 different school management programs in low- and middle-income countries and found that interventions from these management systems did not improve factors such as completion rates and did not have any significant effect on learning outcomes. However, in instances where the program included creating school improvement plans, decentralizing financial-decision making, and generating annual report cards on school performance, there was an improvement in learning outcomes (Snilstveit, 2016[136])

In the past several years, a number of countries have implemented national standards to assess students' learning outcomes. Together with formative assessment practices, summative assessment systems influence the way teachers teach and students learn. In particular, formative assessment practices can enhance students' achievement (Black and Wiliam, 1998[137]). However, there is a large variation in the implementation of formative assessment practices, which has also been reported in recent studies in the United States, Canada, Sweden, Scotland, Singapore, and Norway, among others (DeLuca et al., 2015[138]; Hopfenbeck, Flórez Petour and Tolo, 2015[139]; Jonsson, Lundahl and Holmgren, 2015[140]; Hayward, 2015[141]; Ratnam-Lim and Tan, 2015[142]; Wylie and Lyon, 2015[143]).

Domain-specific constructs in the SCQ include administrators' reports of the use of mathematics achievement data in accountability systems. General constructs in the SCQ include administrators' reports of monitoring teacher practices, feedback to teachers, assessment use in the school, and school evaluation.

Figure 5.21. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.21. Constructs in assessment, evaluation, and accountability module



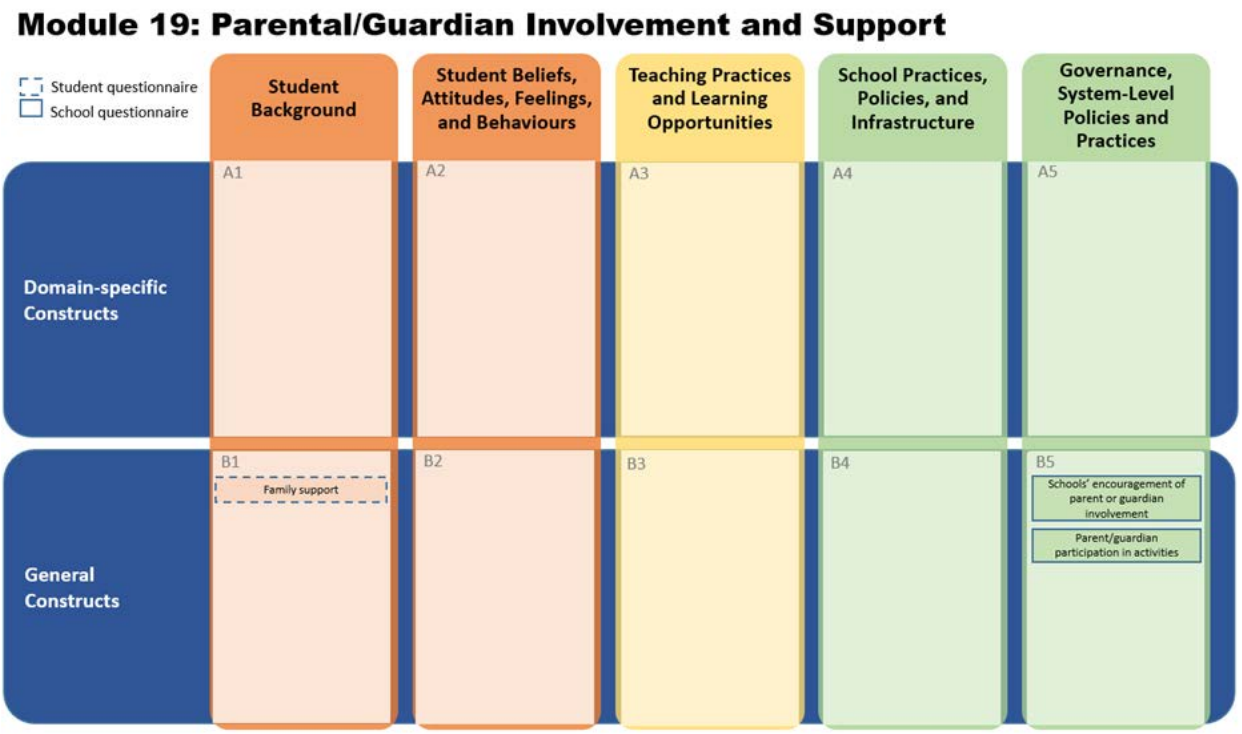
Parental/guardian involvement and support

Parents and guardians are an important audience as well as powerful stakeholders in education, and open communication and collaboration between school leadership and students' parents or guardians are essential to student success. Parental/guardian involvement in education has been conceptualized as parents' or guardians' interactions with schools and their children to encourage academic success (Hill and Tyson, 2009[144]). This involvement is multidimensional and includes school-based involvement (e.g., attending parent-teacher meetings, volunteering at school, or participating in school governance), home-based involvement (e.g., assisting with homework; participating in intellectual enrichment activities not directly related to school but that help develop children's cognitive and metacognitive processes), and academic socialization (i.e., parents' or guardians' educational goals and expectations for their children in general and in specific subjects, and the ways in which these goals and expectations are communicated) (Epstein, 2001[145]; Hill and Tyson, 2009[144]; Kim and Hill, 2015[146]; Murayama et al., 2016[147]). Parental/guardian involvement may also vary by whether the participation is initiated by parents or guardians, students, teachers, or schools. For example, analyses of PISA 2012 data from seven countries have found that school principals' reports of parent-initiated involvement related positively to between-school differences in student achievement, while within schools, parent reports of teacher-initiated involvement related negatively to student achievement (Sebastian, Moon and Cunningham, 2017[148]).

In addition to parents' or guardians' involvement in school activities, the support provided in the family plays an important role in fostering student learning and helping children and adolescents develop confidence, stress resistance, and other social and emotional characteristics important for academic and non-academic success. Several meta-analyses show a positive relationship between parental involvement in education and student achievement (Fan and Chen, 2001[149]; Hill and Tyson, 2009[144]; Jeynes, 2007[150]; Kim and Hill, 2015[146]), and parents' academic socialization of their children was found to have a strong positive relationship with achievement (Fan and Chen, 2001[149]; Hill and Tyson, 2009[144]; Kim and Hill, 2015[146]). This correlation generally held across race and ethnicity and when accounting for socioeconomic differences within the United States (Jeynes, 2007[150]; Kim and Hill, 2015[146]).

Figure 5.22. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.22. Constructs in parental/guardian involvement and support module



Creative thinking

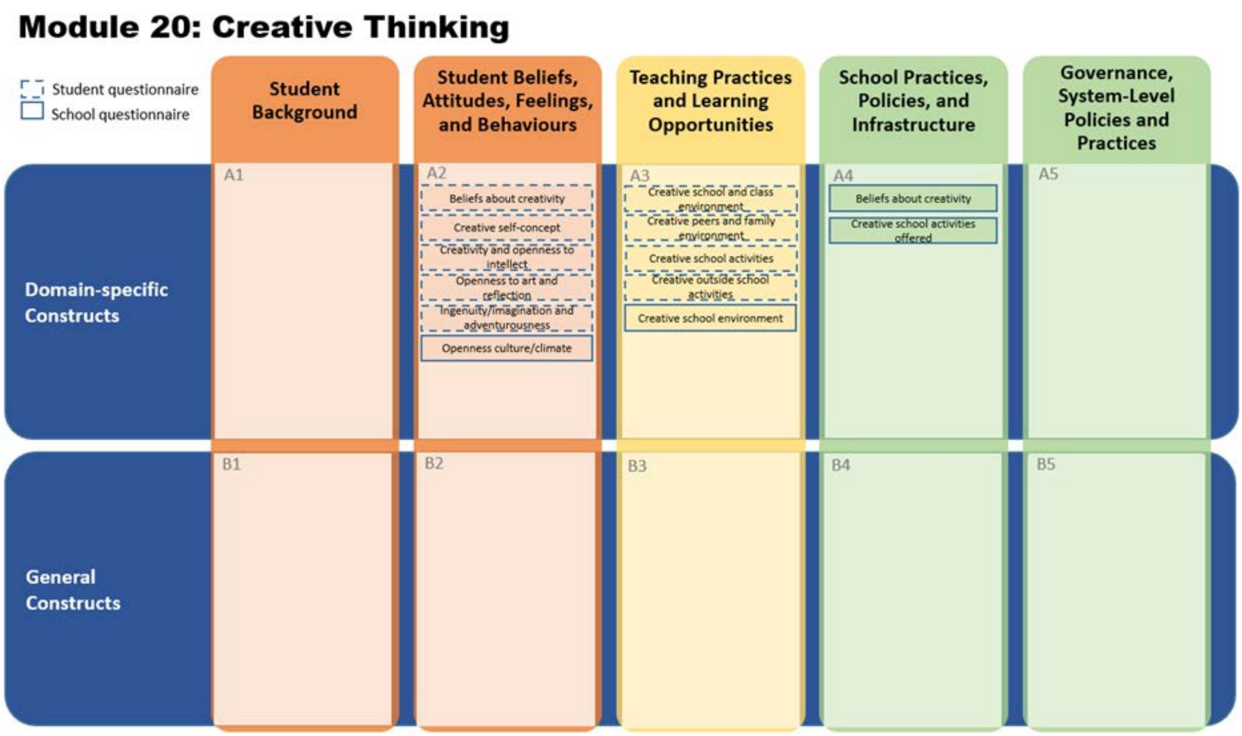
For PISA 2022, creative thinking is defined as "the competence to engage productively in the generation, evaluation and improvement of ideas, that can result in original and effective solutions, advances in knowledge and impactful expressions of imagination" (OECD, 2019[151]). Creative thinking is a necessary competence that can benefit student learning by supporting the interpretation of experiences, actions and events in novel and personally meaningful ways; by facilitating understanding, even in the context of predetermined learning goals; and by promoting the acquisition of content knowledge through approaches that encourage exploration and discovery rather than rote learning and automation (Beghetto, Baer and Kaufman, 2015[152]; Beghetto and Kaufman, 2007[153]; Beghetto and Plucker, 2006[154]). It can help students adapt and contribute to a rapidly changing world that requires flexibility and 21st century skills that go beyond core literacy and numeracy (OECD, 2019[151]).

According to the creative thinking framework for PISA 2022, this competence is fostered by a combination of internal resources, or "individual enablers", and influenced by features of the students' social environment, or "social enablers" (OECD, 2019[151]). Schools are settings in which students' manifestations of creative thinking can be observed. Individual enablers of creative thinking include students' cognitive skills, domain readiness (i.e., domain-specific knowledge and experience), openness to experience and intellect, goal orientation and creative self-beliefs (i.e., willingness to persist towards one's goals in the face of difficulty and beliefs about one's own ability to be creative), collaborative engagement (i.e., willingness to work with others and build upon others' ideas), and task motivation. Social enablers of creative thinking include cultural norms and expectations, educational approaches (e.g., the outcomes an education system values for its students and the content it prioritises in the curriculum), and classroom climate (e.g., teacher and school practices that encourage or stifle creative thinking). The PISA contextual questionnaires aim to collect information on those enablers and drivers that are not directly assessed in the cognitive test of creative thinking.

Constructs in the STQ focus on Creative self-efficacy, Creative school and out-of-school activities, Creative environments, and various facets of openness (e.g., openness to intellect, openness to arts, ingenuity). Constructs in the SCQ focus on school administrators' beliefs about creativity, creative school environment, creative activities offered by the school, and the school's culture or climate of openness. Creative thinking constructs are also included in the optional teacher and parent questionnaires to gather additional information on the beliefs about creativity and creative social environments promoted by these sources.

Figure 5.23. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.23. Constructs in creative thinking module



Global crises

The global spread of COVID-19 in 2020 has created unprecedented academic disruptions around the world, with the closures of schools leading to widespread losses in instructional time for students and the need for schools and education systems to turn to alternative learning opportunities that might mitigate these losses (OECD, 2020[155]). The disruption to schooling will likely have profound short- and long-term impacts on student learning and well-being, especially among students from diverse backgrounds who are more likely to face additional barriers to physical learning opportunities as well as social and emotional support available in schools (OECD, 2020[155]).

In PISA 2022, the global crises module (GCM) includes questions for students and school administrators to capture the experiences of education stakeholders during the COVID-19 pandemic. Constructs in this module are described in an OECD working paper (Bertling et al., 2020[156]). As the module aims to collect information about the educational responses to the pandemic, the questions target one of the most widely implemented responses: the closure of school buildings to students.

Constructs in the STQ focus on the duration of school closure, resources during school closure, subjective perceptions of learning (and learning loss) during school closure, family and teacher support during school closure, and preparedness for future school closures. Constructs in the SCQ capture the number of days that school buildings were closed to students, organisation of instruction, resources available to students, factors hindering remote instruction, teacher communication with students, student attendance in distance learning activities, resources used to support teachers in providing remote instruction, stakeholder support for schools, school preparations for remote instruction, and school's preparedness for digital learning.

Figure 5.24. below illustrates how all constructs in this module map onto the taxonomy.

Figure 5.24. Constructs in global crises module

PISA 2022 Survey Design Principles

PISA has made significant contributions to the enhancement and refinement of survey design principles. However, its previous contextual questionnaire frameworks have not systematically evaluated different methodological approaches or described a comprehensive list of best practices and survey design principles to guide item development. For example, across PISA cycles there have been frequent changes to the number of response options, response option labels, the number of items within scaled indices, or the use of reversed keyed items. Moreover, lack of cross-cultural comparability of questionnaire scales partly due to response styles in PISA is a well-known challenge. While potential strategies for alternative item types (e.g., (Kyllonen, 2013[157])) as well as statistical approaches (e.g., (He et al., 2017[158])) have been explored, these have not always had the expected impact or have not led to noticeable shifts in how PISA data is reported and used. Lastly, measuring the above outlined constructs in PISA 2022 further faces the challenges of implementing robust measurement approaches while keeping student burden low. This framework section presents a clear set of survey design principles that were applied to further enhance construct validity of the questionnaire measures in PISA 2022 and beyond, thereby strengthening the basis for cross-national and cross-cycle comparisons.

Table 5.8. below gives an overview of all principles, each of which will be described in more detail below.

Table 5.8. PISA 2022 Survey Design Principles

PISA 2022 Survey Design Principles	
Question types	1. Continue administering rating-scale type items with common response options grouped into matrix questions but harmonize the length of matrix questions to include fewer items per respondent per screen to balance efficiency with controlling cognitive load and respondent fatigue due to per-screen burden. 2. Continue using alternative item formats introduced during the 2012-2018 cycles (e.g., anchoring vignettes, forced choice, situational judgments tests, slider bars) in cases where there is clear empirical evidence that these methods improve measurement. 3. Minimize the use of fill-in/free response type questions if multiple-choice questions can yield acceptable data to reduce risk of coding inconsistencies and burden on countries for human coding.
Question Wording	4. For new item development, develop balanced scales with both positively and negatively framed items while avoiding double inversions or negations. 5. For new item development, place contextual cues (e.g., “outside of school”, “during mathematics lessons”), if applicable, directly in the item rather than the question stem to improve clarity and reduce wordiness and complexity of question stems. 6. For new item development, avoid double- or multi-barrelled questions. 7. For new item development, harmonize the number of examples in question or balance reading load while avoiding potential student misinterpretations of examples as definitions. 8. For new matrix questions developed to capture reflective constructs, ensure sufficient distinctness of items by avoiding including items that are too similar (e.g., items that share a substantial number of words or repeat phrases used in other items).
Response Options	9. For new item development, use quantifiable frequency response options where possible instead of vague options to facilitate consistent interpretation across all respondents. 10. For new item development, increase the number of response options from 4 to 5 where feasible to allow for more differentiation of responses across students. 11. For trend scales re-administered from previous cycles, do not change response options unless there is fundamental issue with previous options to maximize chances for data-based comparisons across cycles. 12. Display response options in ascending (lowest – highest) order for new questions but retain original order of intact scales retained from previous PISA cycles to facilitate cross-cycle comparisons.
Scaled Indices	13. Continue measuring reflective constructs with multi-item indices scaled based on Item Response Theory (IRT). 14. For new development, establish a minimum number of five items per index to ensure at least a basic level of construct representation.
Routing	15. Use the affordances of the digital delivery platform to use deterministic routing for those questions where collection of more detailed information can be limited to a defined subset of students based on their responses to a previous question that defines a clear routing path.

Matrix Sampling	16. For questions reflective of latent constructs and designed for scaled indices, use a within-construct questionnaire matrix sampling design whereby individual students answer a subset of five items from a larger set of items for each construct. 17. For questions representing manifest or formative constructs and designed for simple indices, collect data on each question from every student. 18. Due not use matrix sampling for any question associated with the Index of ESCS to maximize comparability with previous cycles.
Use of log file data	19. Make questionnaire assembly decisions informed by timing data, to the extent that data from previous cycles or other testing programs is available. 20. Utilize log file data to detect response patterns that may impact the quality of collected survey data (e.g., straight lining, rapid responding). 21. Explore use of log file data to enhance survey-based measures of student test-taking motivation (e.g., timing data may be utilized to add to a measure of effort during the PISA test).

Question types

Use of Matrix Questions

Table 5.9. below provides an overview of the number of items included in matrix questions across past PISA cycles. On average matrix questions have included between 3 and 6 items, with some exceptions of questions with just two items, as well as a notable number of questions with 7 or more items.

For PISA 2022, the number of items in a matrix across questions will be harmonized to optimize the costs and benefits of using matrix questions over discrete single items. Recent research in the context of the *National Assessment of Educational Progress* (NAEP) showed that data quality of matrix questions is comparable to quality of discrete items, with the main difference that matrix questions take much less time to answer (Almonte and Bertling, 2018[159]). The response time benefit plays out especially the longer the matrix is, given that students have to read the stem initially and that time will be added to the first item response. At the same time, data quality suffers if matrices become too long. For example, findings from NAEP show that missing data rates increase if matrices become too long to fit on one screen without scrolling (i.e., higher missing rates are found particularly for those items at the end of a matrix that are not visible without scrolling). While reminders in the digital platform (e.g., prompts alerting respondents when an item on a page has not been answered) may help remedy these effects, it is not clear whether such reminders are equally well understood by test takers across the wide range of the PISA population.

Table 5.9. Number of Items in matrix questions across PISA Cycles

Number of Subitems	YR2000	YR2003	YR2006	YR2009	YR2012	YR2015	YR2018	Year PISA-D	Total	Average
2 sub-items	0	0	0	0	4	0	0	3	7	0.9
3 sub-items	5	2	3	2	4	6	14	5	41	5.1
4 sub-items	1	1	3	4	8	5	14	2	38	4.8
5 sub-items	2	3	4	5	6	9	10	2	41	5.1
6 sub-items	4	3	6	0	5	4	9	4	35	4.4
7 sub-items	4	0	1	3	0	2	3	1	14	1.8
8 sub-items	2	2	4	0	3	4	2	2	19	2.4
9 sub-items	1	0	0	2	5	2	2	1	13	1.6
10 sub-items	0	2	1	0	1	0	1	3	8	1.0
11 sub-items	1	0	0	1	0	2	0	2	6	0.8
12 sub-items	0	1	1	0	0	0	0	0	2	0.3
13 sub-items	0	0	0	1	1	0	0	0	2	0.3
14 sub-items	0	1	0	0	0	0	0	0	1	0.1
15 sub-items	0	0	0	0	0	0	0	1	1	0.1
16 sub-items	0	1	0	0	1	1	1	0	4	0.5
17 sub-items	0	0	2	1	1	0	0	0	4	0.5
18 sub-items	1	0	0	0	0	0	0	0	1	0.1
24 sub-items	1	0	0	0	0	0	0	0	1	0.1
28 sub-items	1	0	0	0	0	0	0	0	1	0.1
Total	23	16	25	19	39	35	56	26	239	

Note. Green bars denote frequency distributions for individual PISA years, orange bars denote frequencies of total counts across all years, and blue bars denote average frequencies across all PISA years.

Use of alternative item formats

Innovative item formats have been explored extensively across the PISA 2012 and 2015 PISA cycles. For instance, PISA 2012 explored the use of anchoring vignettes, situational judgment test items, overclaiming items, and forced choice (Kyllonen, 2013[157]). PISA 2015 continued using anchoring vignettes and introduced slider bars to take full advantage of the digital delivery platform.

Since the introduction of alternative items formats to PISA in 2012, their use in other LSA context questionnaires has so far found rather limited applications and validity studies have resulted in mixed results (e.g., (Bertling and Kyllonen, 2014[160]; Primi et al., 2018[161]; Stankov, Lee and von Davier, 2017[162]). Anchoring vignettes and situational judgment tests come with the added complexity that they pose greater demands on respondent time than more traditional rating-scale multiple-choice questions in order to fully exercise the benefits of these techniques. For instance, research with PISA 2012 anchoring vignettes showed that the technique could improve cross-cultural comparability of resulting scales when vignettes were applied to self-report items designed to measure the same construct (Bertling and Kyllonen, 2014[160]), which corresponds to the originally proposed application of the technique (King and Wand, 2007[163]), but the application of one or few sets of vignettes to multiple distinct scales capturing entirely different constructs may be problematic from a validity perspective (e.g., (Stankov, Lee and von Davier, 2017[162]; von Davier et al., 2017[164])). Including customized vignettes for every construct in the questionnaire, on the other hand, is not feasible within the time constraints of the PISA STQ administration. The most promising use of vignettes in the context of PISA may not be to recode original student responses but rather consider student responses to vignettes as additional complementary information on students' interpretations of the response options across countries and their use of the entire range of the offered scales (Bertling, 2018[165]).

Situational judgment tests are known for their relatively lower internal consistencies (a finding confirmed by PISA 2012 data; (Bertling, 2012[166])) calling for longer scales in order to meet reliability standards for LSAs. Forced choice items have a similar problem. While promising psychometric models are available that allow for the derivation of normative scales through ipsative data (Brown and Maydeu-Olivares, 2013[167]; Stark, Chernyshenko and Drasgow, 2005[168]), these methods require large numbers of items and pairing of many constructs in order to yield robust results. These conditions are typically not met in LSAs where most constructs are operationalized only through a few items and limited time is available. Mixed results have also been reported regarding test-taker perceptions of forced choice items, with sometimes negative impressions of forced choice items.

The most promising technique so far among the innovative item formats explored in PISA 2012 is the use of overclaiming items to adjust subjective topic familiarity ratings for students' tendencies to overclaim what they know and can do. The technique has been widely used in psychological and educational research ((Bensch et al., 2017[169]; Ziegler, Kemper and Rammstedt, 2013[170]), and recent applications in the context of the NAEP program in the United States, for instance, confirmed promising findings found in the context of PISA 2012. Another benefit of the overclaiming technique is that it comes at a relatively low cost – only few items need to be added to existing scales. Despite these benefits, an important caveat is that the overclaiming technique lends itself only to a very limited number of constructs (i.e., subjective ratings of familiarity with a topic), which makes it less promising as a technique to address cross-cultural equivalence concerns more broadly across a larger range of constructs (e.g., attitudinal or behavioural constructs).

In light of these considerations, the number of innovative item formats in PISA 2022 FT instruments was kept small and limited to those formats for which gains in validity are expected and/or additional relevant information about students' response behaviours can be collected.

Minimize use of open-ended fill-in-the-blank questions

Open-ended questions that ask the respondent to fill-in a response using constrained or unconstrained free text entry may be problematic for several reasons. In addition to concerns about potentially larger response time burden for the respondent, one of the main challenges in the context of PISA is that analysis of resulting data requires an initial step of coding student responses into quantifiable categories, as well as the necessary quality control steps to ensure coding accuracy. Accuracy of open-ended student responses is a well-known issue with regard to the coding of open-ended responses specifically for parental occupation questions (Kaplan and Kuger, 2016[32]; Tang, 2017[33]). PISA 2022 aimed to minimize the use of fill-in/free response type questions except for cases where text entry is limited to a small number of digits (e.g., questions about the number of days per week) to reduce risk of coding inconsistencies and burden on countries for human coding.

Question wording

Use of positive and negative statements

Balancing positively with negatively framed statements in questionnaire items designed to measure bipolar latent constructs is an established tradition in psychological measurement. For bipolar constructs, including both positively and negatively framed statements helps ensure that the entire range of a given construct from both poles of the theoretically defined construct is well represented. For unipolar constructs, which are defined theoretically only with regard to one pole, balancing statements might be less necessary. Balancing statements, however, may be still useful in these cases to minimize the risk of inviting undesired survey responding behaviours, such as "straightlining" (i.e., a response pattern where respondents chose options regardless of their content by creating a straight line across options chosen for several items in a matrix question), and it bears the chance to explore whether additional data cleaning steps may improve the validity and reliability of scales based on such items (Primi et al., 2019[171]; 2019[172]).

On the flipside, researchers have reported that respondents with poor reading proficiency may have difficulty responding accurately to scales that combine both positively and negatively worded items, specifically when negations are used, potentially leading to double-negatives (e.g., “I strongly disagree that mathematics is not one of my favourite subjects.”). This problem may be minimized by refraining from using simple negations of positive statements when writing negatively framed statements (but see (Cacioppo and Berntson, 1994[173])). Table 5.10 below illustrates how negatively framed items can be written without the need to include negations.

Table 5.10. Examples of positively and negatively framed statements

Positively framed statement (examples)	Reversed keyed with negations (examples)	Negatively framed without negations (examples)
I am full of energy.	I am not full of energy.	I tire out quickly.
I finish things I start.	I don’t finish things I start.	I leave things unfinished.
I finish things I start.	I don’t finish things I start.	I leave things unfinished.

Another alternative approach that has been proposed is to present respondents with questions that intersperse items from scales of more or less socially desirable traits, rather than using reverse-scored items (e.g., (Gehlbach and Barge, 2012[174])). Interspersing items from different constructs in one matrix has been implemented in PISA only in a few select cases (e.g., assessment of mathematics anxiety and mathematics self-concept in a combined matrix question in PISA 2012) with the overarching number of items designed to represent a scale being grouped into one single matrix. The idea of interspersing items from different constructs in a common matrix has been recently explored in NAEP with findings pointing to only little differences in the factor structure and reliability of resulting indices. Potential benefits of creating construct heterogenous matrices should be carefully weighed against potential risks, including potentially increased cognitive load due to content variation across items in a matrix.

Contextual cue placement

Questionnaire items often ask students to report a behavioural frequency or indicate agreement with a statement when considering a specific contextual cue that may be provided in the question stem or in each individual item (see Table 5.11. below for an example). While placement of contextual cues in the question stem may seem somewhat more efficient from a reading load perspective, it may be less advisable considering research findings that respondents often place only little attention on reading information in the question stem. Placing an important contextual cue in the question stem bears the risk of students missing this piece of information and, consequentially, providing general rather than specific responses to each item. Recent findings from a large-scale pilot in the context of the United States’ NAEP assessment are in line with this assumption (Qureshi, Alegre and Bertling, 2018[175])

Table 5.11. Examples of contextual cue placement in question Stem vs. Item

Contextual cue placement in stem only (example)	Contextual cue placement in each item (example)
Thinking about your mathematics class, how much do you agree or disagree with each of the following statements? a) I come to class prepared. b) I finish my homework right away. c) I enjoy participating in group activitites.	How much do you agree or disagree with each of the following statements? a) I come to my mathematics class prepared. b) I finish my mathematics homework right away. c) I enjoy participating in group activities in my mathematics class.
Word count: 38	Word count: 40

Avoid multi-barrelled statements

An established key principle in survey methodology is not to combine multiple ideas or statements into a single item because of the resulting multi-barrelledness and statistical confounding of student responses (Dillman, Smyth and Christian, 2014[176]; Gehlbach and Artino, 2018[177]). Table 5.12. below shows examples of double- or multi-barrelled items, alongside alternative wording as single statement items.

Table 5.12. Examples of single- vs. multi-barrelled statements

Double- or Multi-barrelled statement (examples)	Alternative wording as multiple single statement items.
I am relaxed and handle stress well.	Statement 1: I am relaxed. Statement 2: I handle stress well.
I am helpful and unselfish with others.	Statement 1: I am helpful to others. Statement 2: I am unselfish with others.

Choose a meaningful number of examples

A notable number of questions used in previous PISA STQ and SCQ include examples. These examples are necessary to convey what information the respondent is asked to provide and to clarify potential ambiguities of broad terms, such as “classical literature” or “digital devices”. Table 5.13. illustrates that items may differ with regard to the number of examples used and outlines potential validity concerns related to the use of too few or too many examples in an item. In order to maximize the utility of examples in PISA 20221 examples were harmonized to a range of 2-5, where feasible. In addition, country-specific examples should be allowed for inclusion.

Table 5.13. Illustration of questions with different numbers of examples

Number of examples provided	Example item	Potential validity concern(s)
Single example	Which of the following are in your home? Classical literature (e.g., <Shakespeare>) *(from PISA 2018)*	• Students may misinterpret the parenthetical as a definition rather than an example if only a single example is provided.
More than 5 examples	What kind of job does your father have? Machine Operator (e.g., dry-cleaner, worker in clothing or shoe factory, sewing machine operator, paper products machine operator, crane operator, bus driver, truck driver) *(from PISA-D)*	• The long list of examples increases the reading load of the question, and consequentially the cognitive load, which may affect understanding particularly for respondents with lower proficiency levels. • Some respondents may also misinterpret the long list of terms in the parenthetical as a full list of possible exemplars of a larger category rather than as examples.

Minimise surface-level similarities in wording across matrix question items

While most matrix questions used in the PISA STQ and SCQ are designed to measure latent constructs by asking respondents a range of similar, yet related questions, it is important that statements are sufficiently distinct to avoid issues of co-linearity between data collected on each item, which may complicate IRT-scaling and inflated internal consistencies. Moreover, including statements that are too similar in the questionnaire may limit the value of the questions for reporting, unless there is strong reason to keep item wording consistent with previously used items’ wording or for comparability with other studies.

Table 5.14 below provides an example of statements deemed potentially too similar alongside an illustration how surface-level similarities between the items in the same matrix may be reduced.

Table 5.14. Example of questions with surface-level similarities

Scale with potentially too similar items	Rewording of items to reduce surface-level similarities
To what extent do you agree or disagree with the following statements? a) I finish what I start. b) I finish tasks despite difficulties in the way.	To what extent do you agree or disagree with the following statements? a) I finish what I start. b) I complete tasks despite difficulties in the way.

Response options

Number of options

Across the past seven PISA cycles, the STQ and SCQ have used a broad range of rating scale response option sets, most of which included four response options (see Figure 5.25 for an overview).

Based on current knowledge in survey method research, five response options have been proposed as an optimal number for any survey question to collect data of sufficient variability (Revilla, Saris and Krosnick, 2014[178]) and researchers have cautioned against using response options with too few (i.e., two or three; (Lee and Paek, 2014[179])) or too many categories as well as neutral middle categories (Alwin, Baumgartner and Beattie, 2018[180]). PISA 2022 questionnaires will balance the need to have sufficiently many data points along which student responses can be distinguished with the respondents' inability to distinguish too many response options and the desire to keep response options as simple as possible to facilitate translations and adaptations. For new item development, it is recommended to increase the number of response options from four to five where feasible to allow for more differentiation of responses across students and more advanced statistical modelling. At the same time, it is *not* recommended to introduce a fifth (middle) category to the established PISA 4-point agreement scale given its longstanding use in PISA, unless there is a specific reason for the particular construct why a middle category would improve validity or cross-cultural comparability.

Figure 5.25. Previously used rating-scale response options in PISA 2000-2018

Type of response option	Order	Number of Option	Response Label	2000	2003	2006	2009	2012	2015	2018	Total
Agreement	Decrease	4	Strongly agree / Agree / Disagree / Strongly disagree	0	7	5	0	13	2	2	29
Agreement	Increase	4	Disagree/Disagree somewhat/Agree somewhat/Agree	1	0	0	0	0	0	0	1
Agreement	Increase	4	Strongly disagree/Disagree/Agree/ Strongly agree	3	0	0	3	0	7	16	29
Amount	Decrease	4	Very confident/Confident/Not very confident/Not at all confident	0	1	0	0	1	0	0	2
Amount	Decrease	4	Very important/Important/Of little importance/Not important at all	0	0	1	0	0	0	0	1
Amount	Decrease	4	Very likely/Likely/Slightly likely/Not at all likely	0	0	0	0	1	0	0	1
Frequency	Decrease	4	Always or almost always/Often/Sometimes/Never or rarely	0	0	0	0	2	0	0	2
Frequency	Decrease	4	Frequently / Sometimes / Rarely / Never	0	0	0	0	5	0	0	5
Frequency	Decrease	4	In all lessons/In most lessons/In some lessons/Never or hardly ever	0	0	1	0	0	1	0	2
Frequency	Decrease	4	Very often/Regularly/Sometimes/Never or hardly ever	0	0	1	0	0	1	0	2
Frequency	Increase	4	Almost never/Sometimes/Often/Almost always	1	0	0	1	0	0	0	2
Frequency	Increase	4	Never or almost never/A few times a year/A few times a month/Once a week or more	0	0	0	0	0	2	1	3
Frequency	Increase	4	Never or almost never/About once a week/2 to 3 times a week/Almost every day	0	0	0	0	0	0	0	0
Frequency	Increase	4	Never or almost never/Some lessons/Many lessons/Every lesson or almost every lesson	0	0	0	0	0	3	2	5
Frequency	Increase	4	Never or hardly ever/A few times per year/About once a month/Several times a month	1	0	0	0	0	0	0	1
Frequency	Increase	4	Never or hardly ever/In some lessons/In most lessons/In all lessons	0	0	0	3	0	0	1	4
Frequency	Increase	4	Never or hardly ever/Once or twice a year/About 3 or 4 times a year/More than 4 times a year	1	0	0	0	0	0	0	1
Frequency	Increase	4	Never/One or two times/Three or four times/Five or more times	0	0	0	0	0	1	1	2
Frequency	Increase	4	Never/Rarely/Sometimes/Always	0	0	0	0	0	0	1	1
Frequency	Increase	4	Never/Some lessons/Most lessons/Every lesson	2	0	0	0	0	0	0	2
Frequency	Increase	4	Never/Sometimes/Most of the time/Always	1	0	0	0	0	0	0	1
Amount	Decrease	5	Very much like me/Mostly like me/Somewhat like me/Not much like me/Not at all like me	0	0	0	0	2	0	4	6
Amount	Increase	5	Not at all true of me/Slightly true of me/Moderately true of me/Very true of me/Extremely true of me	0	0	0	0	0	0	1	1
Amount	Increase	5	Not at all true/Slightly true//Very true /Extremely true	0	0	0	0	0	0	2	2
Frequency	Increase	5	Never or almost never/A few times a year/About once a month/Several times a month/Several times a week	0	0	0	1	0	0	1	2
Frequency	Increase	5	Never or hardly ever/A few times a year/About once a month/Several times a month/Several times a week	4	0	0	0	0	0	0	4
Frequency	Increase	5	Never/A few times a year/About once a month/Several times a month/Several times a year	0	0	0	1	0	0	0	1

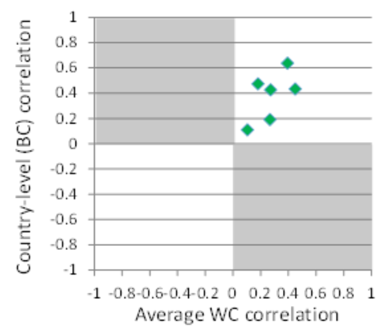
Note: Green bars denote frequency distributions for individual PISA years; orange bars denote frequencies of total counts across all years.

Use of agreement and frequency scales

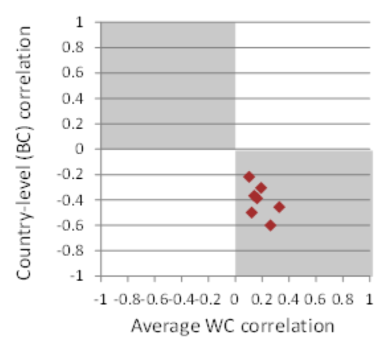
While the overwhelming majority of questions in past PISA cycles have used agreement-type response options (see Figure 5.25), decades of survey methodological research have demonstrated a range of issues with this type of verbal framing of questions, including their proneness to acquiescence response bias and high cognitive burden (e.g., (Revilla, Saris and Krosnick, 2014[178])). Bertling and Kyllonen (2014[160]) have shown that scales in the PISA 2012 STQ were especially prone to the so-called "Attitude-Achievement Paradox" (i.e., a phenomenon whereby scales correlate positively with achievement within a group [e.g., country] but correlations flip to the negative when aggregated group-level data [e.g., country-level data] is considered) when positively framed agreement response options were used. In contrast, scales using negatively framed agreement response options or behavioural frequency response options were not affected by the phenomenon (see Figure 5.26 below). These findings seem to indicate that frequency-based response options may be preferable over agreement-type options.

Figure 5.26. Scales affected vs. not affected by attitude achievement paradox in PISA 2012

Scale	Framing	Construct	Correlations with Achievement		
			TOT	BC	WC
Behavioral	+	Min in<class period> - <Math>	.04	.11	.11
Likert	-	Disciplinary Climate	.19	.47	.18
Behavioral	+	Perceived Control of Mathematics Performance	.24	.19	.27
Behavioral	+	Experience with Pure Math Tasks at School	.27	.43	.27
Behavioral	+	Familiarity with Math Concepts	.44	.64	.39
Behavioral	+	Math Self-Efficacy	.43	.43	.45



Scale	Framing	Construct	Correlations with Achievement		
			TOT	BC	WC
Likert	+	Attitude towards School: Learning Outcomes	.08	-.22	.10
Likert	+	Math Work Ethic	.04	-.50	.12
Likert	+	Instrumental Motivation for Mathematics	.07	-.37	.14
Likert	+	Math Interest/ Intrinsic Motivation for Mathematics	.06	-.39	.16
Likert	+	Perseverance	.13	-.30	.19
Likert	+	Openness for Problem Solving	.18	-.60	.26
Likert	+	Math Self-Concept	.26	-.46	.33



(Analyses based on PISA 2012 FT data)

Source: (Bertling & Kyllonen, 2014)

Note: TOT= correlation with achievement for total (pooled) sample across all countries; BC= between-country correlation based on aggregated country-level data; WC= average within-country correlation across all countries.

It should be noted that response option type and construct were confounded in the aforementioned analyses in PISA 2012, which is why additional research in the specific context of PISA is recommended prior to considering *replacement* of agreement-type questions with frequency-type questions across all constructs. Please note, many of the constructs described in the previous sections, especially the outlined social and emotional characteristics, by definition entail a subjective (and possibly culturally dependent) component and metric or scalar invariance across different cultural groups may therefore be unwarranted. While most of these subjective constructs have traditionally been assessed with agreement type scales, different possible response option sets for PISA 2022 have been explored in cognitive interviews and the international FT. For PISA 2022 response options that allow for more informative and less ambiguous reporting to technical and non-technical audiences were given priority. Table 5.15. summarises which response option sets are used in PISA 2022).

Table 5.15. Response option sets in PISA 2022

Scale type	Response options	Use in PISA 2022
Agreement	Strongly disagree – Disagree – Agree – Strongly agree OR Strongly disagree – Disagree – Neither disagree nor agree – Agree – Strongly Agree	• Retained for re-administration of previously used PISA questions or questions from other OECD surveys (e.g., SSES) • Avoided in new questions
Abstract Frequency	Never– Rarely – Sometimes – Often – Always	• Retained for re-administration of previously used PISA questions only • Avoided in new questions
Absolute Approximate Frequency	Never – About once or twice a year – About once or twice a month – About once or twice a week – Every day or almost every day	• Used for new questions
Relative Approximate Frequency	Never or almost never – Less than half of the lessons – About half of the lessons – More than half of the lessons – Every lessons or almost every lesson	• Used for new questions

Harmonizing directionality of response options

Figure 5.27 below shows how the directionality of response options for the most commonly used PISA questionnaire response options changed since the first PISA cycle in 2000. While response options were administered strictly in ascending order in 2000 and 2009, response options were administered strictly in descending order in 2003, 2006, and 2012. The 2015 and 2018 cycles used a hybrid approach where most questions used ascending order but some questions introduced in earlier cycles were kept in descending order. While harmonizing the directionality of response options in PISA 2022 would likely improve the student experience by making it more consistent across the questionnaire, statistical concerns about backwards comparability of data need to be taken into account. Past FT experiments for PISA 2015 had shown notable effects on item parameters of the direction of response options, and therefore the direction of response options for scales retained from previous PISA cycles will remain unchanged.

Figure 5.27. Variation in directionality of response options from PISA 2000-2018

2003, 2006, and 2012 used **descending order**

Response Option Labels	2000	2003	2006	2009	2012	2015	2018
Strongly agree/Agree/Disagree/Strongly disagree	0	57	43	0	82	10	9
Strongly disagree/Disagree/Agree/Strongly agree	22	0	0	20	0	36	65

2000, 2009, 2015, and 2018 used (mostly) **ascending order**

Note: Green bars denote frequency distributions for individual PISA years.

Scaled indices

Distinguishing manifest, reflective, and formative constructs

The constructs outlined in this module can be distinguished into constructs that are manifest in nature (i.e., are directly observable and reportable based on respondent answers to a single question) and constructs that are not directly observed and cannot be reported on based on respondent answers to a single question but require the creation of indices for reporting. The latter category can be further differentiated into reflective constructs and formative constructs (for an overview see (Bollen and Lennox, 1991[181]); (Edwards and Bagozzi, 2000[182])). Table 5.16. below lists some examples from the PISA context for manifest, reflective, and formative constructs.

Table 5.16. Examples of manifest, reflective, and formative constructs in PISA

Manifest constructs in PISA (examples)	Reflective constructs in PISA (examples)	Formative constructs in PISA (examples)
Parental Education Parental Occupation Mathematics Class Periods per Week	Sense of Belonging Mathematics Self-efficacy Perseverance	ESCS

Reflective constructs can be formalized into latent variable models, which often make a unidimensionality assumption of a single statistical cause that determines responses on the items reflective of the construct (MacCallum and Browne, 1993[183]). Social science usually assumes constructs are reflective (Bollen, 2002[184]), and most of the student attitudes, values, and beliefs constructs described in this framework fall into this category: the underlying trait determines how students think, feel, and behave in certain situations.

In contrast, formative constructs are theoretically inconsistent with latent variable models. Socioeconomic status is often considered the archetypical example of a formative construct (e.g., (Bollen and Lennox, 1991[181])). Another example from PISA that would classify as formative are students' OTL in Mathematics. Unlike the case with reflective constructs, indicators such as parental education or students' exposure to certain type of mathematics problems are not assumed to be caused by ESCS or OTL respectively. Instead, different levels of ESCS or OTL are assumed to emerge when a set of theoretically defined components are combined together. As a result, changes to the item composition necessarily changes the construct. Formative constructs therefore are less suitable for the use of IRT modelling (Howell, Breivik and Wilcox, 2007[185]).

Number of Items per Scaled Index

Despite the consistency in scaling indices based on IRT, there is considerable variation with regard to the number of items used in scaled indices across the questionnaires from PISA 2000 – PISA 2018. Some reflective constructs have been targeted with a single item (e.g., Growth mindset) or very few items (e.g., Sense of purpose) whereas 10 or more items were used to scale other constructs (e.g., Familiarity with Mathematical Concepts). Table 5.17 lists additional examples for short and long questionnaires scales across the last three PISA cycles.

Table 5.17. Examples of short and long questionnaire scales in PISA

Examples of short student questionnaire scales (5 items or less)		Examples of long student questionnaire scales (8 or more items)	
Less than 4 items	• PISA 2018: Growth Mindset (1 item) • PISA 2015 and 2018: Life Satisfaction (1 item) • PISA 2018: Attitude Towards School; Sense of Purpose (3 items)	8 items	• PISA 2012: Mathematics Self-Efficacy • PISA 2015: Science Self-Efficacy; Collaboration
4 items	• PISA 2015: Interest and Valuing of Science • PISA 2018: Motivation, Performance Anxiety	9 items	• PISA 2012: Sense of Belonging; Cognitive Activation; Mathematics Work Ethic • PISA 2018: Positive and Negative Affect; Test Language Reading Activities
5 items	• PISA 2012: Perseverance; Enjoyment of Problem Solving • PISA 2015: Test Anxiety • PISA 2018: Enjoyment of Reading; Perspective Taking	10 or more items	• PISA 2012: Familiarity with Mathematical Concepts (13 items); Home Possessions (17 items) • PISA 2015: Science Learning Activities (10 items) • PISA 2018: Engagement in Global Issues (10 items)

While including single items or very short scales may be appealing from the administration perspective, it might be problematic from the measurement perspective. In order to provide valid and reliable measurement of most contextual variables and additional constructs across participating education systems, it is crucial to rely on multiple indicators for the construct at hand.

PISA 2022 will continue measuring reflective constructs with multi-item indices scaled based on Item Response Theory. For new development, a new lower bound of five for the number of questions in any index was established to ensure reasonable levels of internal consistency and construct representation.

Routing

When PISA questionnaires were delivered on paper, the possibilities to customize individual student experiences through routing were extremely limited. The transition to the digital delivery platform in 2015 opened new possibilities for a routing approach, whereby respondents receive different questions based on their responses to previous survey questions. The approach has been used for specific questions, such as to administer follow-up questions, but it has so far not been widely used to increase the efficiency of collecting data for key PISA constructs, such as ESCS.

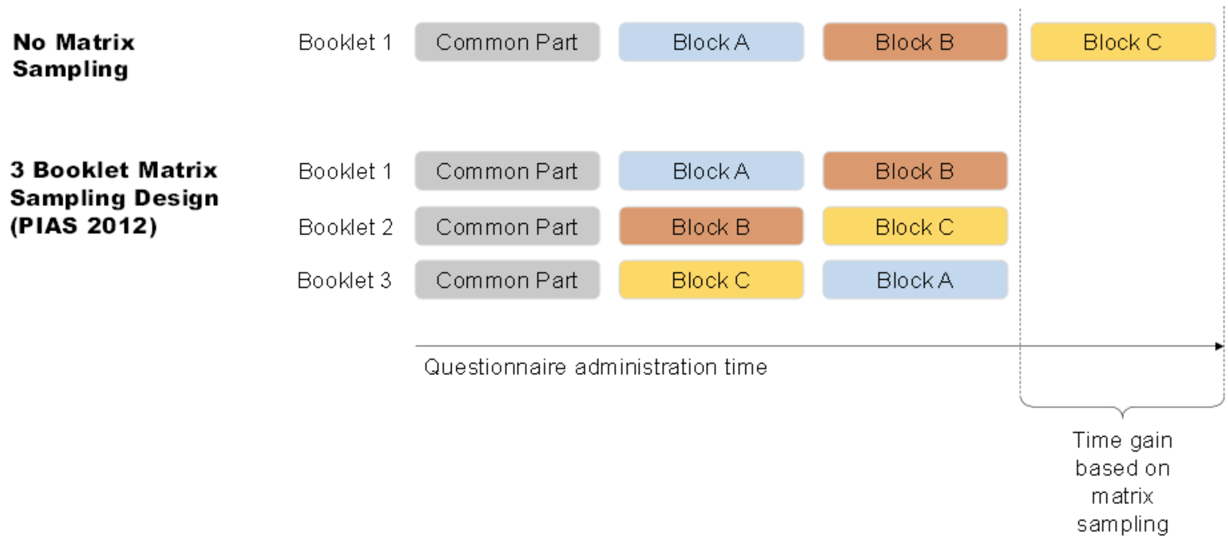
Beyond the measurement of ESCS, deterministic routing and skip patterns will be used for manifest constructs where a clear path can be specified a priori. When introducing routing, an additional important consideration is how to provide countries that will administer questionnaires on paper with an as seamless as possible respondent experience.

Matrix Sampling

Constraints of overall testing time and the large sample sizes in large-scale assessments make matrix-sampling approaches, whereby different respondents receive different sets of items, a viable option to reduce burden while maintaining content coverage across relevant areas. Matrix-sampling approaches are the standard practice for the subject-area tests in educational large-scale assessments (Comber and Keeves, 1973[186]; OECD, 2013[187]) and have more recently been used as an alternative to single-form questionnaire designs.

PISA 2012 utilized a three-booklet questionnaire matrix sampling design whereby individual students received one of three possible booklets containing only a subset of all survey questions administered. This approach, which is illustrated in Figure 5.28., allowed for testing a total of 41 minutes of questionnaire material in the main survey with each individual student's time limited to 30 minutes, i.e., the design allowed for collection of data on 33 percent more questions than in previous cycles without increasing individual student burden (Adams, Lietz and Berezner, 2013[188]).

Figure 5.28. Schematic illustration of the PISA 2012 3-booklet matrix sampling design



A disadvantage of the 2012 three-form design was that entire constructs were rotated rather than rotating individual items within constructs. Thus, one student might answer questions on certain constructs while another student might answer questions on entirely different constructs, but no student answered questions on all constructs. While many researchers reported very small to negligible impact on the overall measurement model, including conditioning and estimation of plausible values (Adams, Lietz and Berezner, 2013[188]; Almonte, 2014[189]; Kaplan and Su, 2014[190]; Monseur and Bertling, 2014[191]), methodological concerns about possible attrition in sample size when conducting multivariate regression models and biases in the estimation of plausible values under the construct-level 2012 rotation design have also been raised (von Davier, 2013[192]).

PISA 2015 and 2018 reverted back to a single questionnaire form and extended the questionnaire time from 30 to 35 minutes to find a compromise between providing a non-matrix sampled data set and including more variables than feasible to include in a 30-minute booklet.

Over the past five years, research has advanced and brought forward new insights about risks and benefits of using matrix sampling for questionnaires, including the exploration of alternative approaches that may prevent the challenges encountered with the 2012 design (e.g., (Bertling and Weeks, 2018[193]; Bertling and Weeks, 2018[194]; Kaplan and Su, 2016[195])).

PISA 2022 will utilize an alternative matrix sampling design to the one used in PISA 2012, which would rotate questions within constructs instead of across constructs.

Figure 5.29. Comparison of construct-level missing data structure resulting from alternative matrix sampling approaches

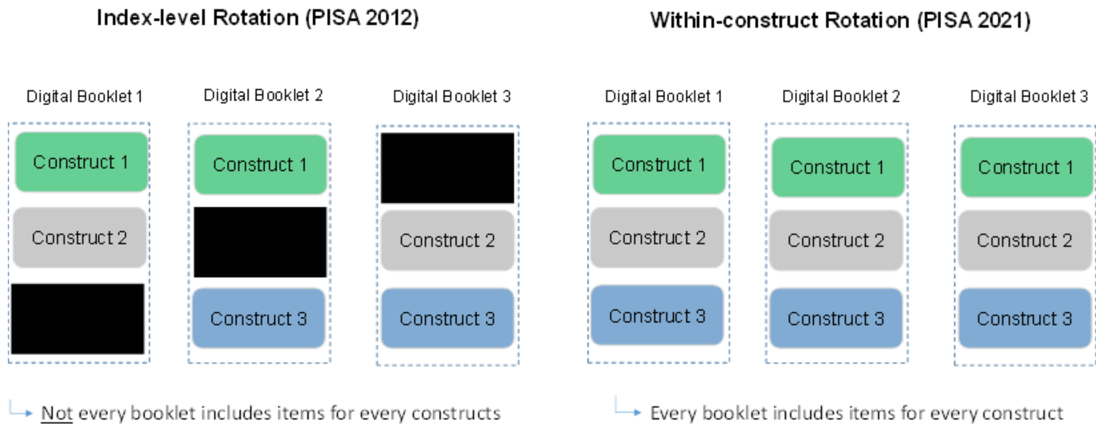


Figure 5.29. illustrates the differences between index-level and within-construct matrix sampling designs in terms of construct-level missing data. Unlike the PISA 2012 design, in the PISA 2022 design, every student will receive questions on all constructs but only answer a subset of all questions for each construct.

Bertling and Weeks (2018[193]; 2018[194]), presented findings from a series of simulation studies using PISA 2012 and PISA 2015 data to the PISA TAG and QEG and concluded that there is no statistical reason to rule out within-construct matrix sampling as a potential operational design for the PISA 2022 MS. Differences found in a first study between fixed vs. random selection of anchor items and rotated items were practically negligible, suggesting that both designs would be feasible in PISA (Bertling and Weeks, 2018[193]). Results from a second study (Bertling and Weeks, 2018[194]) clearly indicated that within-construct matrix sampling with a random choice of rotated items offers the best results among different matrix sampling approaches. Moreover, findings are in strong support that a design where five items are randomly selected from each item matrix will offer superior data for backwards trend analyses than a single form shortened five item scale or designs with anchor items.

Based on discussing a range of possible alternative designs with the PISA TAG and evaluating the new design during the FT stage, PISA 2022 will utilize a design where a random set of five items per construct (drawn from a set of 8-10 items total for each construct) is administered to each student for those questions designed for the creation of scaled indices.

Log file data

Since 2015, the PISA assessment has made the transition to computer-based formats. Besides the answers to cognitive and context questionnaire material, the electronic assessment platform captures basic test takers' behavioural data, also known as log-file data (OECD, 2017[196]). These log-file data can be used for various purposes. For instance, in PISA 2015 and 2018, the answering time was used to guide content selection after the FT. This practice continued during the analysis of the PISA 2022 FT data.

Survey response behaviours captured by log-file data may also be used to relate to cognitive processes (Almond et al., 2012[197]; Couper and Kreuter, 2013[198]; Naumann, 2015[199]; Yan and Tourangeau, 2007[200]). In recent studies, log-file analysis has been used to measure motivation (Hershkovitz and Nachmias, 2009[201])), or to link answering behaviour to aspects of personality (Papamitsiou and Economides, 2017[202]) or students' learning styles (Agudo-Peregrina et al., 2014[203]; Efrati, Limongelli and Sciarrone, 2014[204]).

Accordingly, research interest in this area is growing rapidly. While the Programme for the International Assessment of Adult Competencies (PIAAC) study has published an online LogData analyzer tool that allows for easy access to these data for secondary analyses, open access to PISA log data is still missing. The PISA questionnaires in 2022 will once again be assessed via a CBA platform, thus the captured log-file data could potentially be used in secondary research analyses to explore relationships between answering behaviour and outcomes, in addition to informing content selection post-FT.

As fundamental research is missing on the relationship between context indicators as assessed by tests and questionnaires and corresponding data from log-files, making the PISA data accessible for further research seems to be a promising starting point. Although (Jude and Kuger, 2018[205])point out that currently "no theoretical frameworks exist specifying which kind of log-file data would be the most promising to contribute additional information in ILSAs," making these data accessible could help researchers explore theories, compare relationships in different countries, and help to identify new item types that would yield useful log-file data in future PISA cycles.

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6 PISA 2022 ICT Framework

This section presents the theoretical framework for the way in which PISA 2022 assesses the integration of information and communication technologies in teaching and learning (ICT). This framework provides a comprehensive strategy to document how students access and use ICT resources in and outside of school, and to identify how teachers, schools and education systems integrate ICT into pedagogical practices and learning environments. The framework allows for an exploration of how system-level factors influence schools' and students' experiences with ICT, how the availability and use of ICT interact with various teaching practices, and how these associations correlate with students' performance in mathematics, reading and science, and with other outcomes, such as students' ICT skills and well-being.

Introduction

Why develop a framework to assess the integration of information and communication technologies in teaching and learning?

Information and communication technologies (ICT) play an increasingly important role in virtually all aspects of our daily lives. Not only is technology profoundly transforming people's work and professional life, but it is also altering how people interact, communicate, retrieve and share information, and even how governments provide public services to citizens. ICT also significantly affect multiple facets of education. They can provide new opportunities for students to learn outside of school, and can change teachers' pedagogical approaches and the learning experience of students in school. Moreover, education systems are increasingly embedding digital competencies in their curricula.

ICT are integrated into schools and learning in three major ways:

- Students' engagement with ICT (both in and outside of school) can affect their cognitive processes and their well-being, and eventually what they learn.
- Teachers are increasingly using ICT for instruction, and administrative and communication purposes, with numerous implications for classroom management, instructional practices, pedagogical approaches and time use.
- Competence in using ICT and digital literacy are being recognised as important skills that students need to acquire if they are to flourish in the digital age.

The increasing importance of digital technologies in education systems and the pressing need to equip students with digital competencies raise major policy concerns for governments: To what extent should students use ICT in and outside of school, and how should they engage with these technologies? Are ICT used for learning, for social networking or for entertainment? How and to what extent do teachers of different kinds use ICT and for what objectives? What role do ICT play in different types of pedagogical and instructional practices? Which practices work best with ICT? What are the implications of the different types of ICT use for students' proficiency in mathematics, reading and science? Do certain types of ICT use affect students' well-being? What should governments do to ensure that young people today and tomorrow are sufficiently skilled in the use of ICT to flourish in this digital century?

Despite the growing body of literature focusing on the relationships between students' engagement with ICT and education outcomes, there is no consensus on the contribution ICTs make to students' educational attainment or cognitive performance in general. Although there is little doubt that coming generations are more likely to have the ability to engage with the latest ICT, one should not take for granted that everyone will have access to ICT resources, or that they will use ICT in ways that are responsible and beneficial to them (i.e. that contribute to their personal development and well-being) and to society.

Moreover, although some studies have documented students' access to and use of ICT resources at home and in school across countries (e.g. (Fraillon, Schulz and Ainley, 2013[1])), much remains to be investigated regarding the influence of ICT availability, quality and use on students' academic, and social and emotional outcomes.

This framework explores these questions in the context of the Programme for International Student Assessment (PISA). In all previous rounds, starting in 2000, PISA documented various dimensions of access to and use of ICT by 15-year-old students in and outside of school. For example, in PISA 2000 students were asked whether a computer was available to them in different locations. From 2009 onwards, PISA documented the types of ICT resources available to students at home and in school separately. Depending on the PISA rounds, students' ICT use in school or at home, and their attitudes towards ICT were also documented (OECD, 2013[2]; 2016[3]; 2017[4]).

Yet, ICT questionnaires in previous PISA studies were developed in an ad-hoc way, without a comprehensive ICT assessment framework. This resulted in a number of shortcomings. For example, questionnaires covered mainly hardware and access to the Internet while software and digital learning resources were covered to a lesser extent. The quality and accessibility of these resources were not systematically documented; and, more important, the use of ICT resources was only partially documented, with limited coverage of teachers' pedagogical practices related to ICT.

Objectives of the PISA 2022 ICT Framework

This framework provides a comprehensive strategy to document how students access and use ICT resources in and outside of school, and to identify how teachers, schools and education systems integrate ICT into pedagogical practices and learning environments. The framework allows for an exploration of how system-level factors influence schools' and students' experiences with ICT, how the availability and use of ICT interact with various teaching practices, and how these associations correlate with students' performance in mathematics, reading and science, and with other outcomes, such as students' ICT skills and well-being.

By leveraging PISA's wide coverage of constructs and countries, the framework contributes substantially towards filling the knowledge gap in this field. This framework will guide the development and integration of ICT-related questions into background questionnaires for the PISA 2022 cycle. As such, it will govern data collection on key dimensions of ICT availability and use in and outside of school in more than 50 countries. In addition, the questionnaire will focus on different school actors, such as students, teachers and principals, and on system-level variations in policies across countries.

A critical objective of the PISA ICT questionnaire is to answer a variety of policy questions. Using data collected through this questionnaire, countries should be able to obtain an accurate picture of their respective situation – notably through between- and within-country comparisons – in terms of access to and use of ICT resources by 15-year-old students in and outside of school. Additional important policy questions that this questionnaire aims to answer include: What are the main determinants of and obstacles to using ICT for teaching and learning in schools? How does using ICT for teaching interact with pedagogical practices, and does it relate to students' achievement in mathematics, reading and science? What kinds of digital learning materials, professional development initiatives and teaching approaches should be supported? How the integration of ICT in schools articulates with equity issues both in terms of access to and practices with ICT resources? How do students use ICT outside of school, and is it related to their cognitive achievement and well-being?

This ICT assessment framework covers three major dimensions:

- access to ICT, which encompasses availability, accessibility and quality of ICT resources with a special focus on (connected) technologies that can support learning (e.g. digital learning resources, learning management systems, etc.);
- use of ICT, which covers the intensity as well as the types and modalities of ICT use by students in an informal, and possibly unsupervised, environment for learning and leisure, and in a supervised situation in the classroom, notably through teachers' pedagogical practices with ICT;[1] it also includes alternative uses of ICT by teachers to support teaching; and
- students' ICT competencies, which describe the core competency areas identified in existing assessment frameworks for "digital literacy" as well as attitudes and dispositions towards ICT use (for learning and for leisure). A self-efficacy measure is proposed to assess students' ICT competencies.

The framework is organised in five parts: (i) overall conceptual framework; (ii) description of the system-level factors affecting both access to and use of ICT; (iii) approach to explore access to ICT resources; (iv) examine the variety of ICT uses; and (iv) conclusion by presenting PISA approaches to assess students' outcomes and by proposing a strategy to measure students' competencies in ICT.

Overall conceptual framework guiding the assessment of students' interaction with ICT in PISA 2022

Overall framework

At the heart of the PISA 2022 ICT framework is the relationship between two major dimensions of ICT – access and use – and students' outcomes (cognitive performance, well-being, and ICT attitudes and competencies). However, the framework also aims to identify how these links depends on contextual factors or background characteristics, and on existing policies and practices related to ICT. Figure 6.1 provides an overview of the underlying logical framework used to elaborate the PISA 2022 ICT framework.

Students' use of ICT resources is conditional upon the availability, accessibility and quality of those resources. Conversely, the amount and type of ICT resources made available to students is also influenced by how and why ICT are used. Documenting access to ICT therefore aims to answer the following policy question: To what extent is student engagement with ICT determined by the availability of diverse and functional ICT resources? Consequently, the use of ICT is considered as a second step – a logical continuation. As such, the assessment of ICT use aims to answer the following question: Given the available ICT resources, how are students' uses of different kinds of ICT related to teaching practices and to students' cognitive performance, well-being and ICT skills?

Although this framework recognises the diverse ways in which ICT are used in school, its prime interest lies in documenting students' use of ICT. Yet, ICT are integrated in schools without necessarily involving students' use of them. For example, school principals can use ICT to administer and manage financial and educational resources; and teaching staff can rely on ICT to improve overall instruction, identify and monitor students' strengths and weaknesses, or communicate with parents. Since these practices are likely to affect students' experiences, they are covered by this framework.

Nevertheless, the structure and scope of PISA better fits a thorough examination of the use of ICT at the student level rather than at the school or teacher level. Indeed, optional questionnaires for teachers were distributed in only 17 of the countries/economies that participated in PISA in 2015; and students cannot be matched with a specific teacher, as the sampling of teachers occurs at the school level. Thus information based on teachers' reports only contributes to between-school analyses, and student-level information is needed to capture within-school variations in students' ICT use.

The framework also acknowledges the influence of contextual factors, and policies and practices, on both access to and use of ICT resources, and on students' outcomes. Contextual factors include the general background characteristics of the education system, schools and students' households. They include, for example, the level of economic development of a country; students' grade level in secondary school; the integration of ICT literacy in the curricula; whether the school is public or private; the socio-economic and cultural background of students and parents; and even teachers' qualifications. These elements are not specific to ICT, and overlap with the information found in the PISA background questionnaires at the student, parent, teacher, school and system levels. Although not directly related, these factors are likely to shape and constrain the degree of access to ICT resources, and how they are used. They are also likely to affect the relationship between access to and use of ICT, on the one hand, and student outcomes, on the other.

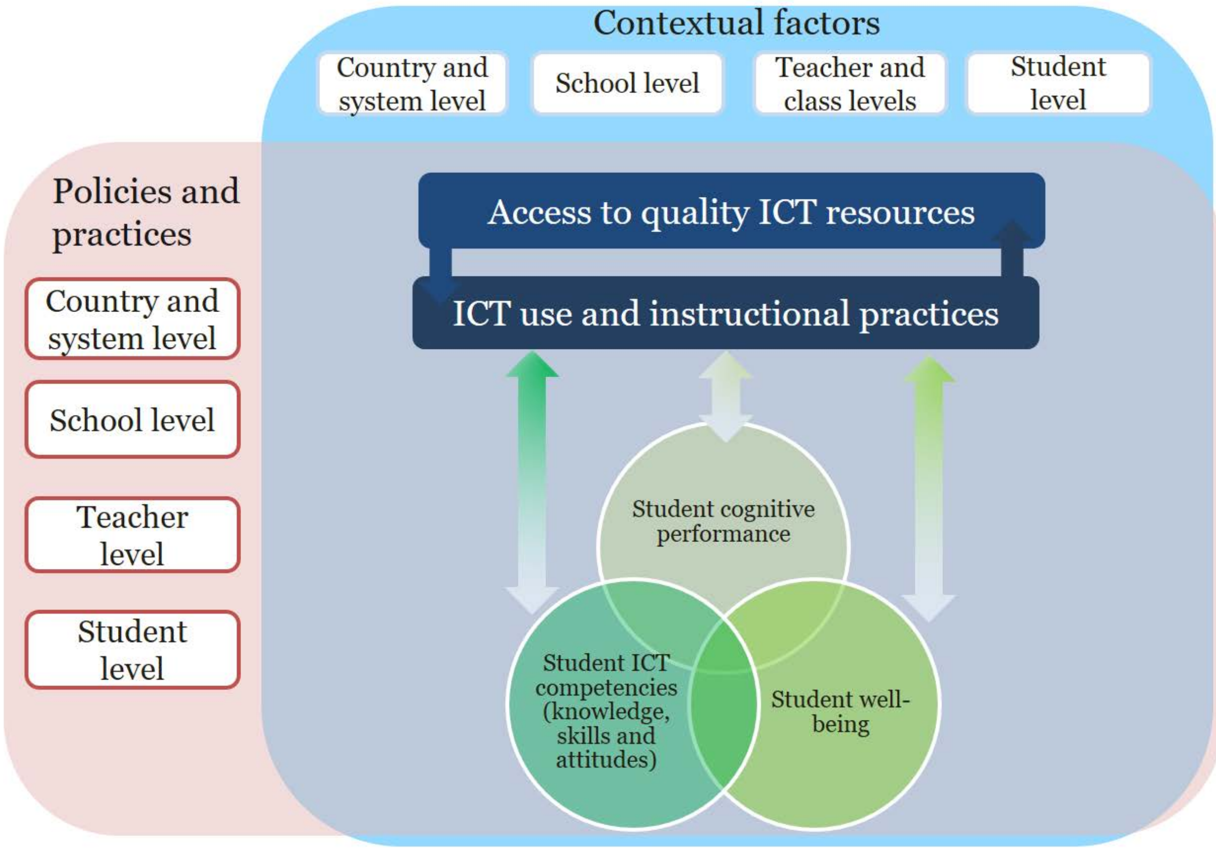
In addition, specific ICT-related policies and practices could directly influence access to and use of ICT resources. Such policies include, for example, the existence of specific funding for ICT resources in schools, principals' attitudes towards ICT use as an instructional tool, and guidelines and support for teachers in using ICT in the classroom. These policies and practices could also be developed as a response to students' cognitive performance or their attitudes towards ICT.

This logical framework applies to students' engagement with ICT both in and outside of the classroom, and covers a variety of stakeholders, including students, teachers, principals and parents.[2] This does not imply that students' access to and use of ICT is conceived in an entirely similar way in both contexts. Indeed, there are crucial differences between having a teacher present as an intermediary to students' engagement with ICT in the classroom and using ICT for leisure or learning purposes outside the classroom. For example, teachers can select relevant digital resources ex ante, explain how to use them efficiently and ensure students are focusing on the learning tasks. Yet, the specificities of ICT use in and outside of the classroom fit into the broader conceptual approach presented in Figure 6.1. The particularities of both contexts are detailed thereafter.

As mentioned earlier, the PISA 2022 ICT framework examines the relationship between students' use of ICT and three outcomes: students' cognitive achievement, well-being and their level of ICT competencies. The assessment of students' cognitive achievement in mathematics, reading and science and students' well-being is not specific to this framework; it relies on the respective frameworks dedicated to each outcome during previous PISA cycles. By contrast, the PISA 2022 ICT framework develops a specific strategy for documenting students' ICT competencies, which are regarded as including both knowledge and skills related to ICT use and attitudes toward ICT. The framework includes ICT skills that were identified using existing ICT competence frameworks (e.g. (Fraillon et al., 2015[5]; Carretero, Vuorikari and Punie, 2017[6]; Fraillon, Schulz and Ainley, 2013[1])). The objective is to provide directions for the development of a proper assessment of ICT literacy in future PISA cycles.

However, the assessment of ICT competencies in PISA 2022 will not rely on a test, as is the case with mathematics, science and reading. Instead, it will rely on students' self-reported attitudes and self-efficacy measures regarding ICT use for learning and leisure. Assessments of both students' attitudes and self-efficacy will build on similar measures developed in previous PISA cycles in relation to the major domain being tested. Particular attention will be given to ensure the validity of the self-efficacy measure, which can be challenging, as seen in previous assessments. Indeed, students' confidence in performing advanced ICT tasks is weakly associated with Computer and Information Literacy (CIL) achievement scores as measured in the International Computer and Information Literacy Study (ICILS) test (Fraillon et al., 2014[7]). Ensuring the validity of the self-efficacy measure requires the coverage of a wide array of tasks pertaining to different dimensions of digital competencies (by including technical skills as well as skills related to communication and information literacy among others).

Figure 6.1. PISA 2022 ICT conceptual framework



Source: Authors

Relationship between access to and use of ICT resources

As shown in Figure 6.1, the availability, accessibility and quality of ICT resources partly shape teachers' and students' practices with ICT, both in and outside of the classroom. Indeed, the total amount of ICT equipment available per student is likely to affect decisions on whether and how to use ICT resources. One could imagine that having fewer than one computer per student at school would mean that students use computers in group exercises, for example. Similarly, the ease with which ICT can be accessed during class could affect the work arrangements and frequency of use.

In addition, the quality of ICT resources for learning – encompassing dimensions as diverse as technical capacity and performance, teacher (or pedagogical) and student usability (e.g. ergonomics and ease of use), practicability and adaptability – would likely affect the range and relevance of the activities that could be conducted with the available ICT equipment. For instance, slow Internet connections would prevent students from using demanding online digital learning resources, while students working on poorly maintained computers would likely encounter software compatibility or obsolescence issues. In addition, an educational software could be accessible and engaging to students but not flexible enough to fit a teacher's pedagogical approach or not in line with the curriculum. Access to and use of ICT outside of school for learning are vulnerable to similar constraints. However, the assessment of the quality of ICT resources for other purposes, such as leisure, has to rely on different measures, although some of the aspects mentioned above could still be relevant.

Conversely, students' and teachers' use of ICT can also affect decisions about the selection of and attention devoted to ICT resources. Indeed, the extent to which students use ICT resources for learning science or mathematics could guide the selection of specific software and hardware requirements, and mandate a certain level of Internet bandwidth, for example. Similarly, if teachers rely on ICT mainly for personalising the pace of students' learning, for obtaining instant feedback or for collaborative group exercises, that could affect their school's decision about whether to purchase a computer for each student, to invest in individualised learning software, or instead to invest in online collaborative games and Intranet installations.

Moreover, teachers' attitudes towards the use of ICT as a tool for instruction are likely to influence the amount and types of resources they use in class and available in schools. A similar relationship applies for students' use of ICT outside of the classroom. Indeed, students' use of ICT for leisure could be affected by their (and their parents') attitudes and practices. For example, parents aware of the opportunities and risks of ICT use could encourage their children to play educational or collaborative video games or simply limit the access to the game console or computer.

The strength of the inter-dependence between access to and use of ICT resources, and the relative importance of each of the effects described above, strongly depend on how responsibilities are shared across the different levels of the education system. In a centralised system, access to ICT resources may be almost entirely determined at the system level, with a limited relationship to actual ICT use at the school level. By contrast, if the school enjoys more autonomy in acquiring educational resources and encouraging teaching practices using ICT, teachers may be more involved in selecting the equipment they need to pursue their pedagogical strategies. Including ICT skills in the curriculum or adhering to security regulations may also affect schools' and teachers' ability to use and provide access to ICT resources. Indeed, the curriculum might favour the use of particular ICT resources while security regulations might prevent schools and teachers from conducting specific activities.

ICT use in the classroom

The conceptual framework can be further refined by describing how ICT use by students and teachers in the classroom can influence student outcomes. The aim is to postulate hypotheses that will serve as a basis for investigation. This section details three main ways that ICT use in school may be related to student outcomes (Figure 6.2).

First, students can use ICT resources to learn a traditional subject, such as mathematics, reading or science. ICT-assisted instruction can affect students' cognitive performance (and other outcomes) through its interaction with teaching strategies and students' engagement with learning. Teachers' instructional practices prior to ICT integration into teaching are likely to affect how ICT is used in the classroom. Conversely, the integration of ICT can also change the use and modalities of teaching strategies, pedagogical practices and classroom arrangements (including teacher or student-centred instruction, traditional or enquiry-based teaching, and assessment and feedback practices for pedagogical purposes). Thus, the relative weight and overall combination of the different teaching practices (i.e. teacher-directed instruction, student-focused instruction, teacher support, and feedback and adaptive teaching) are expected both to guide how ICT are used and to vary with the use of ICT in the classroom.

Moreover, teachers' use of ICT can affect subject-specific teaching strategies, such as using simulations in mathematics. Using ICT as a tool to learn a specific subject can also affect students' engagement with learning, as manifested in the time spent receiving instruction, and students' concentration on, efforts in and attitudes towards the subject. Teachers may introduce more ICT tools into classrooms precisely in order to attract students' attention.

The practical use of ICT for learning also entails challenges. Teaching practices that rely on ICT require teachers to have specific skills and know-how about the learning process and classroom management with digital tools. Integrating digital resources in teaching could also initially require a substantial investment of time and effort in preparing course materials, classroom management and monitoring the success of the teaching approach. Moreover, the use of ICT for different activities could make it more challenging to maintain a quiet, peaceful and respectful classroom in which students can concentrate on academic tasks, and listen to the teacher and other students. Another related challenge is the potential misuse of ICT by students who could spend a substantial amount of their time in class on social networks, games and other distracting activities.

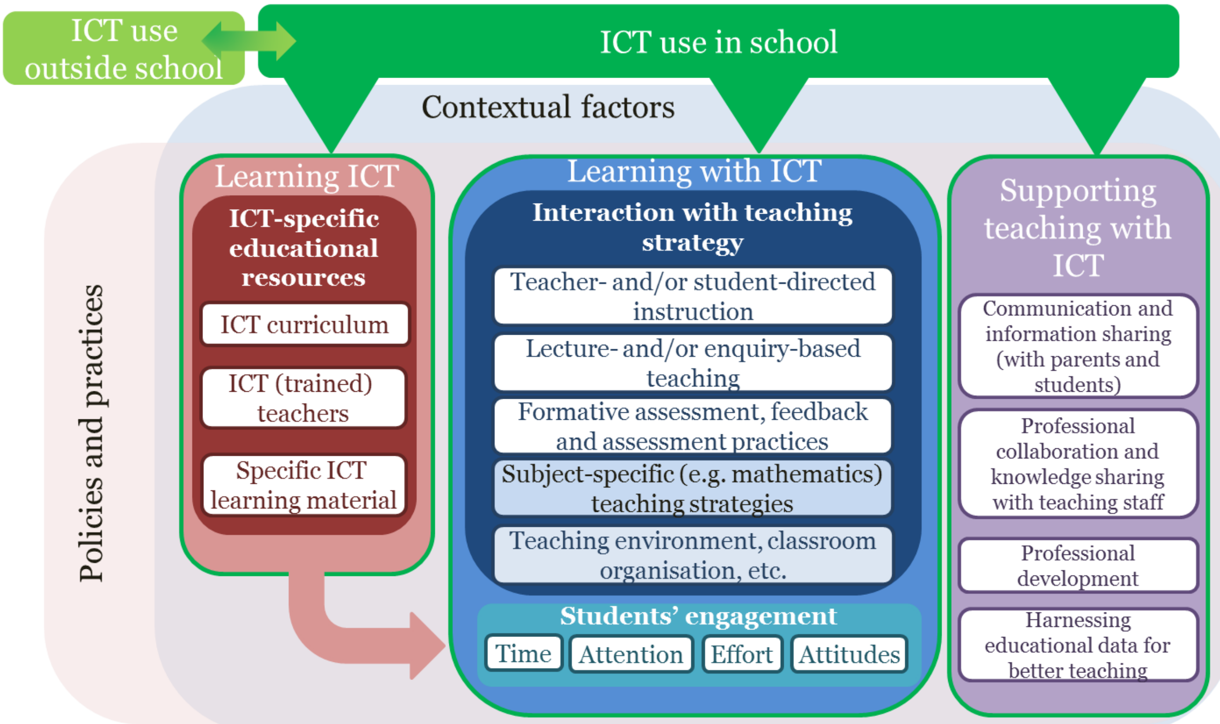
Second, students can benefit from specific teaching about ICT – either in a dedicated course or time period – aimed at improving ICT-related competencies. The benefits for students will depend on the availability of specific ICT educational resources. In particular, students could benefit from ICT teachers or teachers with particular qualifications for delivering ICT courses. They can also have access to learning resources specifically designed to develop ICT competencies.

In this regard, more and more education systems are integrating computational thinking (i.e. "a problem-solving methodology that expands the realm of computer science into all disciplines, providing a distinct means of analysing and developing solutions to problems that can be solved computationally", ACM et al., 2016) into secondary education curricula, either across subjects or as a stand-alone course. This is often accompanied by in-service training for teachers, and the use of specific instructional practices and tools in the classroom, including "unplugged" activities, simulations and using coding software (Bocconi et al., 2016). Students' activities with ICT outside of school could also be more directly related to certain ICT competencies, such as handling troubleshooting and security issues or engaging in diverse use of social media.

In addition to the expected direct effect on students' ICT competencies and attitudes, acquiring ICT skills can make it easier for students to use ICT to learn other subjects. Specific instruction in ICT can also raise students' awareness about the potential effects of ICT use on their well-being. But investing time and effort in teaching ICT skills could take resources away from instruction in other subjects and thus have a negative effect on students' cognitive performance.

Third, ICT can be used to support teachers' activities outside of the classroom. For instance, teachers can use ICT to communicate with colleagues, and to contribute to the development of overarching and transversal pedagogical practices. ICT can also be used to communicate with parents and create online communities, bringing together teachers, parents and students. Teachers can also rely on ICT to plan their courses, share materials with students, and keep track of students' work and performance. Overall, ICT can simplify administrative tasks and processes, thereby freeing up time for more meaningful activities that could benefit students' performance and well-being.

Figure 6.2. Detailing ICT use in school



Source: Authors

ICT use outside the classroom

Education policies can affect only part of students' use of ICT outside of the classroom. Using ICT outside of school depends on factors as diverse as students' socio-economic status, local Internet and broadband coverage, and the price of ICT resources. ICT activities are also affected by parents' attitudes towards ICT use at home, the availability of digital learning resources at school, and national policies regarding the safe use of the Internet.

Unlike using ICT in the classroom, which is assumed to be solely for learning, students use ICT outside of the classroom both for learning – either for completing homework assignments or for self-motivated learning activities – and for leisure (Figure 6.3). Although these modes of ICT use are possibly connected, each has a specific relationship with cognitive performance, well-being and ICT competencies (Figure 6.3).

Students use ICT outside of the classroom in a variety of situations, and the type of equipment and the purpose of ICT use are likely to vary substantially, depending on the situation. For example, students can use ICT resources available in their school during their free time to complete their homework, use the family computer or their own device during the weekend to browse the Internet or play video games at a friend's home after school.

An important distinction between ICT use in the classroom and outside of school is that the latter usually takes place in an unsupervised environment, although ICT use at home could be supervised, to some degree, by a household member. However, the increasing use of digital resources for home assignments and project-based learning activities tend to blur the boundaries between school and out-of-school activities. Indeed, many ICT tools offer teachers the ability to monitor students' activities on line, whether they take place in or outside of school. As in previous PISA cycles, this framework distinguishes between students' use of ICT during school days and during weekends, and documents whether the use of ICT takes place at home or in another location.

Students' use of ICT resources for learning outside of the classroom may have significant consequences for their engagement and success in school. Several important aspects of students' use of ICT for learning outside of the classroom are likely to be related to students' outcomes.

ICT may have an effect on students' engagement with their homework. Students who feel positive and at ease with ICT in any situation may spend more time on, invest greater effort in, and have more favourable attitudes towards homework if they can use ICT to complete their assignments. By contrast, students who have no or limited access to ICT resources and do not feel comfortable using them for learning may give up on homework more easily if it requires the use of ICT. Moreover, students who use ICT for completing homework assignments at home could be distracted by the many ways ICT can be used for leisure instead.

The effect of ICT use not only on students' motivation but also on learning is likely to vary with the type of homework assigned and whether it was designed for ICT. In particular, the development of innovative pedagogical approaches, such as project-based learning facilitated by technology-supported collaboration tools, enquiry-based learning, the use of simulation tools or online laboratories, might facilitate learning by doing, foster students' engagement and motivation, and help students develop problem-solving skills by putting students in various novel situations and encouraging them to adopt different perspectives (OECD, 2016[8]).

Second, using ICT for learning could help parents and teachers assess their children's/students' efforts and strengths, and monitor and address any problems that may arise. Eventually, this could lead to better diagnoses and greater parental engagement, both of which can have positive effects on students' cognitive performance. Again, the effect will depend on parents' and teachers' attitudes and competencies regarding ICT; negative attitudes could widen the digital divide.

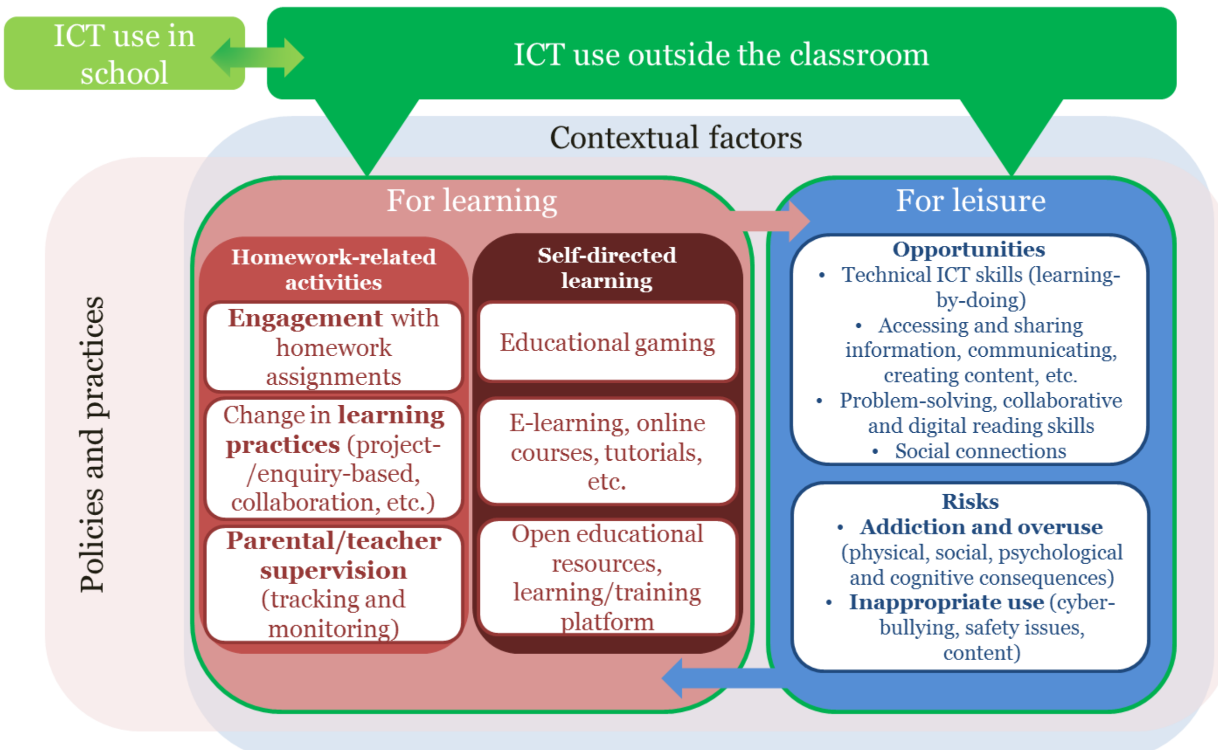
Third, students can also use ICT for learning in a variety of contexts unrelated to homework. Students might conduct research via the Internet to learn about specific topics of interest. They may also use digital learning resources because their parents or friends advised them that it could improve their skills in a specific subject. In addition, the boundaries between ICT use for learning and for leisure might become less clear with the development of educational gaming, and with new types of video games that include collaboration, enquiry, problem solving, and strategic components and activities. As a result, learning with ICT may more often be seen as a leisure activity for students with potential benefits for students' cognitive performance, well-being and ICT competencies.

Nevertheless, students are more likely to use ICT outside of the classroom for leisure (European Commission, 2013[9]). When they do, students have many opportunities to develop certain cognitive processes and skills, but they also face certain risks. These risks and opportunities are not related to the use of a specific device or software. Indeed, there are both opportunities and risks no matter whether students use ICT for gaming, accessing social media, browsing the Internet for entertainment or searching for information.

By using ICT for leisure, students can develop specific ICT competencies, including technical skills, such as troubleshooting and understanding security settings, as well as the ability to access, analyse and share information, communicate and create content. There are also a variety of opportunities to develop problem-solving and collaborative skills through, for example, connected, multi-players games, and also more basic skills, such as numeracy, reading and writing. ICT use, notably through social network and digital community interactions, also offer the possibility to develop social and global competencies (OECD, 2018[10]).[3] Moreover, students who do not use ICT may miss opportunities to develop social ties with other students and risk to suffer greater loneliness or exclusion (OECD, 2015[11]).

But students face some risks when using ICT for leisure. The potential lack of self-control combined with the curiosity of adolescent ICT users may lead to overuse and even addiction problems, which could have serious adverse physical, social, psychological and cognitive effects. Students' security and safety could also be at risk, as they could be exposed to cyberbullying or to inappropriate (e.g. violent, pornographic) content (OECD, 2015[11]). Adult guardians can thus play an important role in supervising students' use of ICT while well-designed learning experiences can encourage healthy, responsible and constructive use of ICT.

Figure 6.3. Detailing ICT use outside the classroom



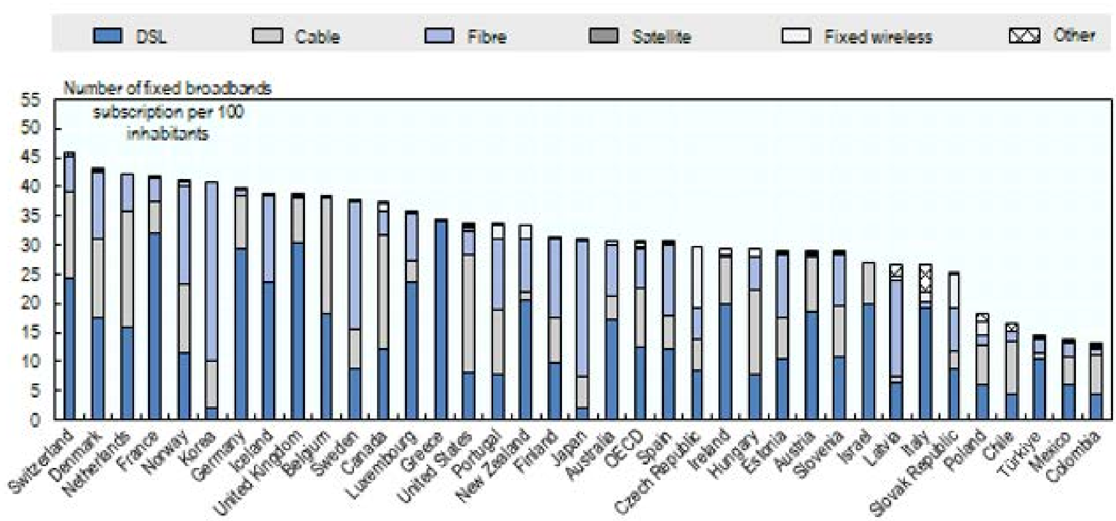
Source: Authors

Country- and system-level factors related to access and use of ICT resources

Although digitalisation is progressing at an impressive rate around the globe, there are substantial differences in ICT access and quality across countries, regions and education systems (OECD, 2015[11]; Fraillon, Schulz and Ainley, 2013[1]; Korte and Hüsing, 2006[12]). For example, as shown in Figure 6.4, the number of fixed broadband subscriptions per 100 inhabitants varies significantly across OECD countries – from more than 40 per 100 inhabitants in Denmark and Switzerland, among others, to fewer than 15 per 100 inhabitants in Mexico and Türkiye. In terms of quality, more than three in four connections in Japan and Korea are fibre connections, while fewer than one in four are, on average, across most other OECD countries, and in Austria and Germany, only one in 50 are fibre connections (OECD, 2018[10]).

These country-level differences could be attributed to variations in contexts and policies. The level of economic development, the structure of a country's economy (especially the development of ICT-enabled services to citizens and businesses), the level of investment in new technologies and the demand for ICT skills determine the availability of ICT resources. In addition, the policies governing the education system and, in particular, the weight given to integrating ICT into learning, influence the availability of ICT in schools.

Figure 6.4. Fixed broadband subscriptions per 100 inhabitants, 2017



Note: Australia: Satellite data are not available for publication.
Canada: Fixed wireless includes satellite.
France: Cable includes VDSL2 THD.
Germany: Cable includes HFC lines; fibre includes fibre lines provided by cable operators; fixed wireless includes BWA subscribers; other includes leased lines.
Israel, Luxembourg, Switzerland and the United States: Data are estimates.
United Kingdom: Terrestrial fixed wireless figures are unavailable. Satellite figures are estimates.
Source: OECD, Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm

Since one goal of the PISA 2022 ICT Framework is to document students' ICT experience, it is crucial to document contextual factors at the country and system levels that affect the availability of ICT resources for the population as a whole, including in the education system and for learning, in general, but also for leisure. In addition to contextual factors, national practices and policies are also likely to shape students' access to and use of ICT resources.

Documenting country-level factors feeds into the analysis in different ways. First, country-level factors provide a useful context for understanding the dynamics of ICT availability and use in within a country; they also facilitate comparisons across countries. Second, those factors offer insights into the quantity and quality of ICT resources available to students, and can be used as a benchmark against which the data collected through PISA can be compared.

Country-level factors affect students' access to and use of ICT resources in two major ways. They contribute to the overall availability of ICT infrastructure in the country (and at the subnational level), including the availability of ICT for learning-related purposes. This affects the availability of ICT resources at school and for learning outside the classroom. In addition, education system-level policies and practices have an impact on the access and maintenance of ICT in schools, and shape students' and teachers' use of ICT resources. Such system-level factors include teacher support for using ICT, qualifications requirements for teachers to use ICT, references to ICT competencies in the curriculum, guidelines regarding specific teaching practices with ICT, and security and safety regulations.

System-level factors are documented from different sources. Information related to contextual factors and the overall availability of ICT are drawn from existing surveys conducted by the OECD, including PISA system-level data collection, the Survey of Adult Skills (a product of the Programme for the International Assessment of Adult Competencies [PIAAC]), and indicators from the OECD Directorate for Science, Technology and Innovation and international organisations (e.g. the World Bank's world development indicators, the ICT Development Index [IDI] developed by the International Telecommunications Union, etc.). Practices and policies, notably regarding the regulations of the education system, will be collected through a new PISA system-level questionnaire addressed to the countries and economies participating in PISA.

Contextual factors affecting the overall availability of ICT resources

Overall access to ICT resources

The availability of ICT resources in a country can be assessed by examining various ICT-related country-level indicators. Relevant indicators at the country level include: the availability of ICT infrastructure; the affordability of ICT resources; use of ICT by the population and government; the quality of ICT resources; inequalities in access; and the demand for ICT skills in the labour market. Several dimensions of ICT development or readiness (which refers to the propensity for countries and economies to exploit the opportunities offered by ICT) at the country level are also key indicators.

- The availability of ICT infrastructure and the quality of ICT resources can be documented by collecting information on mobile network coverage, Internet bandwidth and the types of broadband connection (e.g. digital subscriber line [DSL], cable, fibre, etc.). This may be complemented by information regarding public investment in ICT, the weight of the ICT sector in the economy and the availability of the latest technologies.
- Use of ICT can be documented through information on the number of mobile phone subscriptions per inhabitant, the share of individuals using the Internet, the share of households with a personal computer and Internet access, and the use of virtual social networks, among other indicators.
- The distribution of ICT infrastructure and ICT use can be recorded across population subgroups (for example, gender, wealth, region, immigrant background, etc.) or through an inequality index, to shed light on inequalities in ICT access and use within a country.
- The demand for ICT skills in the labour market is also an interesting measure as it indicates the extent to which developing such skills are rewarded. The share of individuals using generic ICT skills (i.e. for communicating and for searching for information) daily at work varies significantly across countries, ranging from 64% in Norway to 33% in the Slovak Republic in 2014, among the countries that participated in the Survey of Adult Skills (PIAAC) (OECD, 2016[8]).

The aforementioned IDI and the Network Readiness Index (NRI) measure the capacity of countries to leverage ICT for increased competitiveness and well-being; thus, they provide information on other dimensions of ICT, such as the political and regulatory environment, that also helps define the ICT country context.

Access to ICT resources for learning

Documenting the availability of ICT resources supporting learning would also be of great value for characterising the environment in which students and teachers use ICT both in and outside of school. Several dimensions could be covered:

- Information regarding private and public expenditures on education-related ICT would contribute to the country profile in terms of ICT use for learning outside of school. This could be complemented by information regarding the existence of (and amount distributed under) programmes that provide financial support to households for buying education-related ICT equipment, which were found in a third of European countries in 2009 (EACEA, 2011[13]).
- A description of the wealth (or eco-system) of available ICT resources to support learning would also be useful. One could distinguish between initiatives developed by the country or at the

subnational level for all citizens, and the resources developed within the education system and for education stakeholders. In examining the purpose and type of ICT resources, it is important to consider digital learning resources and material (e.g. digital library), digital learning platforms, where learners can track their status as they progress, learning management systems and portals, which enable learners to engage in collaborative projects and communicate with peers and teachers (e.g. file sharing, virtual group rooms, chat, blog and Wiki, local knowledge portals, calendars, specific educational software and digital laboratories, etc.) and ICT-supported administrative resources mainly for administrative and teaching staff to track and monitor students and communicate with parents.

Policy environment governing ICT access and use in education

By and large, education systems acknowledge the central role of ICT in education, but their governance and regulatory frameworks differ substantially, as do their efforts and abilities to progressively adopt ICT in schools. It is critical to understand the policies, regulations and guidelines that determine the direction and evolution of ICT availability and use in an education system in order to understand the differences in ICT environments across countries. Classifying policies and practices by the extent to which they encourage investment in ICT, set rigorous or permissive rules, and provide support to various stakeholders for accessing and maintaining quality ICT resources can help describe the ICT environment students face in school.

The regulatory framework regarding the quantity and quality of ICT resources in schools

Another indicator of the ways in which ICT are integrated in education systems is the existence of a national (or subnational) strategy aimed at guiding ICT use in education. Although countries may take different approaches with regard to ICT in education, such strategies are common (all European countries have one) and therefore seem to be a promising source of information on regulations and guidelines regarding ICT in education (EACEA, 2011[13]). System-level indicators could be collected via the PISA system-level questionnaire and should cover the following dimensions:

Quantity, accessibility and quality: This includes the nature (whether it is legally binding, a measure or a guideline, for example) and the content of rules specifying the ICT resources that schools are entitled to, according to some criteria, such as the number of enrolled students. Whether the school or a higher-level institution is responsible for purchasing and maintaining ICT resources should also be documented. Accessibility also refers to the regulations regarding students’ access to ICT resources, including recommendations on time exposure to specific ICT resources, security and safety guidelines, location and disposition of ICT resources in schools and the required degree of supervision. Quality includes conventions regarding the desirable standards of the ICT equipment and the frequency with which they are maintained and renewed.

Financial resources: A good starting point from which to examine education systems’ relative positions would be to document expenditures on education-related ICT resources. Similar to the measure of cumulative expenditure per student between the ages of 6 and 15 collected in PISA, a measure of cumulative expenditure on ICT resources per student would provide a synthetic estimate of ICT access throughout 15-year-old students’ education. In addition, documenting the rules, recommendations and administrative processes guiding the allocation of funding to ICT resources (including the level at which decisions are made, the degree of autonomy schools enjoy and whether budgetary items are constrained) would provide important insights into the overall ICT education environment in schools.

Human resources: This includes the qualification requirements for teachers in terms of ICT competencies and using ICT to teach, regulations and guidelines regarding the availability of an ICT co-ordinator or support system in school, and information about the overall share of teachers with a specific ICT (for teaching) qualification. In addition, such information would cover the availability, need for and provision of different types of training, including continuing professional development training aimed at building teachers' skills regarding ICT use for educational purposes (either in general, for a specific subject, or related to imparting ICT competencies to students), remedial training to develop ICT skills, or training targeted at principals for the deployment of ICT in schools.

ICT-related pedagogical resources: The availability of ICT resources specifically designed for education purposes is a critical component of ICT resources. In particular, the diffusion to teachers and continuous development of pedagogical resources related to ICT use for educational purposes should be documented. The availability and breadth of a central repository for pedagogical resources, the availability of human resources regarding ICT, the development of exchange platforms for teachers to share their experiences and good practices, and the existence of partnerships with researchers and developers of pedagogical resources can be documented.

Policies and guidelines framing the use of ICT resources by students and teachers in school

The governance of the education system regarding the use of ICT resources in school can vary widely across countries, and even across regions within countries. Information on the overall regulatory environment and guidelines framing teachers' pedagogical practices with ICT and students' use, include:

The degree to which ICT are integrated into the curriculum at different education levels. This refers to both the presence of specific ICT skills to be transmitted to students as part of the curriculum of various subjects, and reference to the use of ICT as a means of helping students acquire knowledge and skills in these subjects. Of particular interest are the inclusion of ICT as a tool for acquiring mathematical skills and the explicit reference to ICT competencies, such as computational thinking, within the mathematics curriculum.

Policies, regulations and guidelines for ICT use in the classroom. These encompass information regarding the degree of autonomy schools (and teachers) have regarding the use of ICT resources. In particular, it should document whether specific restrictions apply when using ICT resources in class, such as a requirement to obtain permission from the legal guardian or principal, the need to supervise the students, restricted access to ICT functionalities and the Internet, or limitations to the amount of time students can spend using ICT resources.

Incentives for or barriers to using ICT for teaching in class. These refer to existing financial or career incentives teachers may or may not receive for using ICT; recommendations available in official documents; and the existence of strict conditions under which ICT should not be used, notably with regard to equity issues in the classroom (e.g. restrictions on the use of ICT if some students do not have ICT resources at home or lack the basic ICT skills necessary to use them).

Evaluation and assessment of ICT competencies and ICT use for teaching. These include determining the existence of mandatory examinations of students' ICT competencies, internal and external evaluations of teachers' practices regarding ICT use for teaching, and specific assessments of teachers (or schools) regarding the adequate use of ICT resources.

Access to ICT resources

Over recent decades, access to ICT devices, such as computers and smartphones, has improved considerably around the world. Indeed, mobile phone subscriptions more than doubled globally between 2007 and 2017, reaching 102 subscriptions per 100 people. With a threefold increase over the same period, sub-Saharan Africa largely contributed to this progression, reaching 74 subscriptions per 100 people (World Bank, 2018[14]). In parallel, the share of individuals using the Internet more than doubled in the past decade, to 46% of the global population in 2017. Again, the evolution in sub-Saharan Africa (from 3.5% to 20%) and in low- and middle-income countries in general (from just over 11% to 39%) has been remarkable (World Bank, 2018[14]). In light of the ICT breakthrough, governments have become increasingly concerned with providing new generations access to high-quality ICT resources and minimising the "digital divide" in the population. Education systems have thus come to play an increasingly important role in promoting universal access to and the responsible use of ICT.

Governments' concerns are legitimate. In spite of the rapid democratisation of ICT, access to ICT has not spread uniformly across all economies, regions and population groups. While nearly all 15-year-old students in OECD countries have access to the Internet (95%, on average), the proportion is much smaller in low- and middle-income countries participating in PISA, such as Brazil (84%), Thailand (71%) and Algeria, Indonesia, Peru and Viet Nam, where fewer than one in two students is connected to the Internet at home (OECD, 2015[11]). Moreover, within countries, differences between advantaged and disadvantaged students in access to computers and the Internet are even larger.[4] Although these differences are small in Denmark, Finland and Hong Kong (China), where more than 99% of disadvantaged students have access to computers, in Brazil, Indonesia, Mexico, Türkiye and 8 other PISA-participating economies, less than 50% of disadvantaged students have access to computers (OECD, 2015[11]).

As ICT resources have become increasingly available, the technical standards required for accessing the latest functionalities and online resources with ease have also steadily progressed. Accounting for the differences in quality of ICT resources (in addition to their availability) would likely further increase the existing "digital divide". Access to ICT resources for 15-year-old students should therefore include a measure of quality, as well as a notion of accessibility, which would reflect the extent to which students can access available ICT resources and whether they face certain constraints.

Previous PISA cycles mainly documented the type of ICT resources available at home or in school. This framework broadens the focus and proposes a systematic and consistent approach to measuring 15-year-old students' access to ICT resources. Availability, accessibility and quality are documented.

- The **availability** of ICT resources documents the presence of a specific ICT resource, which can be used either in class or during students' free time.
- The **accessibility** of ICT resources describes the set of elements that characterises the ease and flexibility with which ICT resources can be accessed. Therefore, it refers to existing rules, norms, configurations and arrangements guiding the access to ICT resources both in and outside of school.
- The **quality** of ICT resources is a multi-faceted concept that refers primarily to the functionality, technical capacity and capability of ICT resources. Quality measures describe the extent to which ICT function smoothly – without flaws, delays or security issues – and are compatible with other ICT resources (hardware or software). In addition, some aspects of availability and accessibility also contribute to the definition of quality, such as the diversity of ICT resources and the quantity available per student. Moreover, dimensions such as the relevance and usability of ICT resources – notably in the context of their use by 15-year olds for learning purposes – are also important for defining quality. These correspond to the degree to which the ICT resources are relevant to the curriculum, create interest among students who can easily work with them, and can be used by for a variety of purposes and adapted to different education settings.

The approach described above is aligned with the interests of policy makers. Many ICT-related policies and programmes involve providing ICT materials to schools and students in varying quantities under different settings. In this context, documenting which ICT resources are available and how easily accessible and functional they are seems relevant from a policy perspective. For example, such information can help benchmark the provision of ICT resources for schools or help ensure optimal utilisation at the system level. Moreover, these factors may constrain or shape how students and teachers use ICT resources – which is the principal avenue for investigating the effects of integrating technologies into learning (OECD, 2015[11]; Conrads, 2017[15]; European Commission, 2013[9]; Schleicher, 2015[16]).

Findings from the literature also support the approach proposed in this framework. Research assessing the impact of policies that provide or facilitate investments in ICT in schools or for students cannot, for the most part, disentangle ICT access from use. In recent literature reviews, Bulman and Fairlie (2016[17]) and Escueta et al. (2017[18])conclude that these programmes (whether they focus on schools or students) have little or no positive effect on most academic outcomes. Thus, as Escueta et al (2017[18])highlight, "simply providing devices to students generally [does] not improve learning outcomes".

Although it is clear that providing ICT resources to schools or students does not necessarily lead to higher learning outcomes, a closer look at the findings uncovers some promising avenues regarding the provision of ICT resources. First, the literature reveals positive effects on computer use and ICT skills acquisition in general (Fairlie, 2012[19]; Malamud and Pop-Eleches, 2011[20]). Second, research suggests that certain digital learning resources may have a positive effect on students' cognitive achievement (Escueta et al., 2017[18]; Jackson and Makarin, 2018[21]). Third, some evidence suggests that improved accessibility to ICT resources (e.g. by decreasing the waiting time to access computers) could explain the benefits observed in some cases when providing additional ICT resources (Fairlie and London, 2012[22]). Finally, accessing ICT resources does not seem to adversely affect well-being indicators, such as social development and personal interactions (Fairlie and Kalil, 2017[23]).

In parallel, the literature also highlights the claim that providing ICT resources may be more useful when targeting post-secondary students (Escueta et al., 2017[18]). Some studies also observe a negative impact on achievement, possibly because using ICT for leisure (such as playing video games) crowds out time spent on homework assignments (Leuven et al., 2007[24]; Malamud and Pop-Eleches, 2011[20]). Improving the quality of ICT resources (in the sense of improved functionality) has not been studied extensively, but a study looking at differences in Internet speed finds no association with educational attainment (Faber, Sanchis-Guarner and Weinhardt, 2015[25]).

Overall, the evidence suggests that documenting the availability, accessibility and quality of ICT resources, with a thorough accounting of those resources dedicated to learning, could help fill a knowledge gap regarding ICT for 15-year-old students.

Availability of ICT resources

There are several constraints to mapping available ICT resources in the context of PISA. First, the surveyed ICT resources must be relevant across PISA countries and economies, consistent with previous PISA cycles, and should remain applicable over time. In addition, there is a need to cover both ICT resources for learning, in and outside the classroom, and for leisure. Moreover, in the context of this framework, the prime interest is to cover ICT resources potentially related to students' well-being, cognitive achievement (in mathematics, reading and science) and ICT skills. In order to fulfil these requirements, the proposed approach distinguishes general ICT, which can be considered as tools, or "functional learning materials" following the terminology of Bundsgaard and Hansen (2011[26]) in the context of learning, from ICT resources specifically designed for learning or for school-related activities.[5]

General ICT resources

ICT resources cover an array of digital tools that can be used for different purposes, including learning and leisure. The diversity of ICT resources available to students can be documented through a two-dimensional approach distinguishing, on the one hand, between hardware and software, and, on the other hand, between ICT for general and for specific use. This framework facilitates the comparison of available ICT resources across students, schools and countries, and helps describe the diversity of those resources.

Hence, general ICT resources range from computers and access to the Internet (i.e. hardware resource for general use) to cameras (hardware resource for specific use), and also include social networking websites or applications (software for general use) and image-processing programmes (software for specific use), among other digital tools.

Overall, the choice of ICT resource identification should ensure that the most common resources are covered. Since very few ICT devices account for most of students' use of digital resources, providing a full mapping of all available digital devices does not seem to be very valuable or feasible. Thus, the aim should not be exhaustive coverage but rather to cover key digital tools whose unavailability would clearly indicate a lack of access to ICT resources. Different sets of ICT resources could be covered depending on whether students' access in school or at home is being investigated. This should reflect the fact that ICT resources are more often used for leisure outside the classroom for specific activities, such as video games.

ICT resources designed for learning

As mentioned above, providing resources specifically designed to enhance learning appears to be a promising avenue for ICT to benefit students' cognitive achievement (Escueta et al., 2017[18]). Although ICT resources for learning mainly include software, classroom equipment, such as interactive whiteboards, projectors or hardware that can be used for this purpose could also be considered. ICT for learning can be diverse, ranging from online educational resources (e.g. specific YouTube channels, or Massive Online Open Courses [MOOCs]) to educational games and even online sharing platforms and intelligent tutoring systems.

The major types of ICT resources for learning can be classified as follows:

- **Digital content for learning**, which includes online courses, digital books and multimedia resources (for the most part, it fits into "semantic learning material" in Bundsgaard and Hansen's (2011[26]) terminology)
- **Communication and tracking tools**, which facilitate communication among schools, parents and students (and as such could be considered as "functional learning materials")
- **Virtual learning environment and intelligent tutoring systems** aimed at helping students practice particular skills, which fall into the "didacticised learning materials" category as described in Bundsgaard and Hansen (2011[26]).

Documenting several attributes of the available ICT resources can help assess the ICT environment. For example, knowing whether a specific ICT resource is connected to the Internet or not, whether students can access the resource outside of school, and in addition, whether the resource was created, conceived or adapted by a teacher or a specialist, would provide information on the degree of interactivity and adaptability of available ICT.

Another important characteristic is whether digital learning resources are subject-specific (or even skills-specific) or whether they can be used for learning different subjects. The aim should be to cover, as a priority, digital learning resources relevant to supporting teaching and learning of all the domains assessed by PISA (i.e. mathematics, reading and science). In addition, it would be of interest to cover digital learning resources aimed specifically at supporting teaching and learning in the major domain assessed by PISA in a particular cycle. Hence, the focus will be on digital learning resources used to teach and learn mathematics in PISA 2022, including software designed to enhance students' engagement with mathematics, online collaborative platforms used by students to solve specific problems or simulation software to be used by mathematics teachers. Covering digital resources and tools relying on, or aiming at developing computational thinking or programming skills (whether this subject is integrated into mathematics or not) would also be of interest. Wide coverage of these digital learning resources is particularly relevant, as Escueta et al. (2017[18]) show that educational software exhibit "enormous promise in improving learning outcomes, particularly when it comes to mathematics".

The question of "availability" raises some concern in this context. Indeed, a number of ICT resources are freely available on line and are therefore accessible as soon as the student has access to the Internet.

Consequently, documenting students' access to online resources should focus on documenting their knowledge of where to find and how to connect to such resources, as well as whether these were made available by the school or the parents. Alternatively, the availability and actual use of these learning resources should be documented simultaneously.

Accessibility of ICT resources

The mere existence of ICT resources, even those of high quality, would be of little benefit if students and teachers could not use them appropriately. Indeed, ICT resources not only have to be available and of good quality, but students and teachers should also be able to access them when needed. Accessibility refers to the degree of availability and the flexibility with which users can reach available ICT resources. While unlimited access to ICT resources is not necessarily beneficial for students (Malamud and Pop-Eleches, 2011[20]), restricted access to ICT resources, notably in schools, can constitute a major barrier to using them (Fairlie and London, 2012[22]).

For available ICT resources, both in school and at home, access can be constrained due to issues related to ownership, the number of ICT resources per person or because of rules related to the organisation and distribution of ICT resources.

Ownership and congestion

In addition to mapping available ICT resources for students, accessibility can be documented through information on ownership. In particular, whether a specific ICT resource belongs to the student constitutes a key dimension of accessibility. Possessing a computer of one's own would likely affect the intensity and diversity of use, for example. Supplementary information about ownership outside of school includes whether the ICT resource belongs to another family member, whether the student is the main user of the device, whether the ICT resource is lent by an organisation or whether the resource is only accessed outside the home (in a library, etc.).

The question of ownership also matters when considering ICT resources at school, as more and more schools rely on "bring your own device" strategies for the use of tablet devices and smartphones (Conrads, 2017[15]). Thus, documenting whether students own the ICT resource in school is of interest. When ICT resources belong to the school, it would be important to collect information regarding the degree of "congestion", including the number of students per computer at the school level, the average time students have to wait to access a computer and, if possible and relevant, the number of students per computer for a specific subject (notably the major domain being investigated in PISA in a given cycle).

Regulations and norms

A variety of regulations could also affect the degree of freedom with which students can access available ICT resources. This can be the case both in and outside of school, although the types of rules are likely to differ significantly.

In school, the rules regarding access to ICT resources may be described in a "code of conduct" or equivalent that determines the type of supervision required for a student to access specific digital equipment, the type of responsibility engaged, the maximum length of time a student can use a specific ICT resource (including the Internet), whether it can be displaced or not (and used at home, for example) and the number of users per device, among other rules. All of these may be part of the administrative process that each student must follow in order to access ICT.

Another way that access to ICT resources could be limited is by the degree of technical restriction. For example, the access to ICT resources could be password-protected; teachers and students may not have access to administrative rights and therefore lack flexibility for accessing relevant learning resources.

In addition, ICT use by teachers and students may be affected by time and space constraints (e.g. classroom size, layout of tables, building design, location of ICT resources in the school). For example, grouping ICT resources in a computer lab may facilitate providing classes in ICT but may hinder the use of ICT for learning (European Commission, 2013[9]). In contrast, placing computers in the classroom can be useful for personalising teaching and learning, and for allowing teachers to use ICT resources more flexibly (Condie and Munro, 2007[27]). Time constraints could arise from queuing time to have access to ICT resources, loss of time when using ICT or simply time pressure to prepare exams and cover the curriculum (European Commission, 2013[9]). Therefore, information about the distribution and placement of ICT resources in the school are important in describing ICT access and use.

For these reasons, collecting information on ICT-related school rules and regulations would largely improve the general understanding of ICT accessibility.

Quality of ICT resources

The quality of ICT resources refers to the technical components of ICT and to the capacity of available ICT resources. Two aspects of ICT-resource quality are covered here: the functionality and maintenance of ICT resources, and the overall degree of connectivity.[6]

The lack of well-functioning and up-to-date ICT resources may constitute a serious obstacle to using them effectively. The European Survey of Schools ICT in Education (ESSIE) examines a set of potential obstacles affecting schools' capacity to provide ICT teaching and learning, and shows that a shortage and inadequacy of ICT equipment are the most significant obstacles that schools face (European Commission, 2013[9]). Indeed, according to ESSIE, more than one in five general grade 11 students in Greece, Hungary, Ireland, Malta, Spain and Türkiye attend schools where the lack of bandwidth mattered significantly in providing ICT teaching and learning in 2013. Moreover, head teachers cite out-of-date and faulty computers as key problems affecting ICT teaching and learning (European Commission, 2013[9]).

The quality of available ICT resources can be documented using indicators of the level of functionality and degree of connectivity. The objective is to document the capacity of available ICT resources. However, this approach does not provide a measure of the quality of ICT resources in terms of their actual or intended use. Indeed, a laptop used mainly for basic office software applications (word processor, presentation software and spreadsheet program) does not require the same technical characteristics needed for more demanding applications, such as online gaming or running mathematical simulations. Therefore, students may have to adapt their ICT use to the limited technical capacity of available ICT resources. To overcome this limitation, an alternative approach would be to document users' assessments of the constraints they face when using ICT resources.

Functionality and maintenance of ICT resources

To make the most of available ICT resources, users should be able to access ICT equipment in order to perform their tasks without flaws, defects, delays or security issues. This depends on a number of factors, including the resources allocated to ICT equipment, indicators of the overall modernity and capacity of the equipment, and routine maintenance practices.

Although imperfect, information regarding the resources allocated to ICT equipment in school and at home could be a good indicator of the standards of ICT. In school, documenting current-year expenditures on ICT resources separately for hardware, software, and digital learning resources would provide an interesting benchmark for quality. Ideally, information on average spending per student and per computer should be available.

Documenting information on the technical characteristics of available ICT resources may be cumbersome and may only allow for limited comparisons. Yet one could consider documenting the basic characteristics of computers, such as, for example, random access memory (RAM), storage capacity and computational power.

This should be combined with information regarding the age of ICT resources and the frequency of replacement, which are not perfect measures of quality when assessed independently, as the better the resources are maintained, the less often they should need to be replaced. Information about the resources allocated to maintaining ICT would be valuable. This would include whether the school can rely on an ICT co-ordinator, and the range of the tasks this person is responsible for, such as maintaining ICT resources, installing new software, etc.

Overall level of connectivity

The degree of connectivity is another central aspect of the quality of ICT resources. The quality of the Internet connection is the first dimension of connectivity. The extent to which available ICT resources can be and actually are connected to the Internet would provide complementary data. Indeed, the Internet is, by nature, both transversal – it is always used in combination with another ICT resource – and transformative – it expands and modifies the possibilities of the equipment with which it is associated. Moreover, as a specific ICT, the Internet also allows for the development of new ICT, such as most smartphone applications, which depend entirely on its existence and availability. Thus, students' access to the Internet should not be documented separately – by collecting information on the type, speed and modalities of available connections – but also in relation to the set of ICT resources available. Collecting information on whether each of the available ICT resources is connected to (or enabled by) the Internet would therefore provide a detailed picture of the degree of students' connectivity.

The overall connectivity of a school is of particular interest when describing the quality of the ICT environment. The type of Internet connection (i.e. broadband, digital subscriber line [DSL], fibre, 4G, 3G, etc.), the modalities of connection (wired or wireless), and the corresponding bandwidths available per student are likely to contribute substantially to the functionality of ICT resources and to students' opportunities to use ICT for different purposes.

In addition, the existence of a school website, a local area network (or intranet), a specific e-mail address for teachers and students, and a virtual learning environment would be indicative of a more connected school environment.

Another dimension of quality is the extent to which ICT resources are adapted to and flexible enough to allow multiple uses. Aspects related to the compatibility of ICT resources with other ICT, and existing constraints regarding the licences and copyrights of software and digital content, would also reveal the flexibility with which ICT resources can be used.

Subjective assessment of shortages and obstacles limiting ICT use

Although indicators of the availability, accessibility and quality of ICT resources are informative, they may be difficult to compare internationally in the context of PISA. Moreover, the extent to which students and teachers are truly constrained by shortages of ICT resources depends on the potential use of those resources. To circumvent these challenges, the various dimensions of the suitability of ICT resources could be assessed through the subjective perception of users, including teachers (or principals) and students. A similar method was adopted in the ESSIE study, in which head teachers' perceptions of obstacles to ICT use for teaching and learning were surveyed (European Commission, 2013[9]).

Following a similar approach, the users (teachers, students, principals) could therefore be asked whether they feel constrained in their capacity to use ICT for teaching and learning due to shortages of ICT resources (distinguishing among hardware, software and digital learning resources), accessibility (location of ICT resources, school regulations, etc.) or quality (Internet connection, out-of-date computers, software incompatibility, etc.).

Since the subjective assessment of the suitability of ICT resources is likely to be affected by the respective attitudes of teachers and students, a complementary approach could be to ask factual questions about users' experiences using ICT. For example, users could be asked whether, in the past two weeks, they had decided to abandon, revise or shorten an ICT-related activity because of the absence of adequate ICT resources, because of difficulties in accessing those resources, or because of faulty, deficient or slow-functioning ICT.

Information regarding the differences between the quality of available ICT resources in and outside of school, and in comparison to the best standards could also be documented. This can capture effects related to the relative quality of ICT resources.

The use of ICT in and outside the classroom

As pointed out in recent literature reviews, merely providing ICT resources is not enough to ensure that they are used effectively to improve students' cognitive achievement, well-being and ICT competencies ((Bulman and Fairlie, 2016[17]; Escueta et al., 2017[18]). Although the positive impact of ICT use on student achievement remains subject to debate, there is a consensus that the specific purpose, context and pedagogical practices surrounding ICT are central to their effect on students.

This section begins by describing the various ways ICT are used by students in the classroom, with a particular focus on the pedagogical practices that were previously found to be successful in shaping cognitive achievement. It also provides a brief description of the overall school environment, which partly shapes teachers' and students' use of ICT in the classroom. Next, it examines students' ICT use for learning and leisure outside the classroom and highlights important contextual factors.

Students' use of ICT in the classroom

Teachers' pedagogical practices and teaching strategies with ICT largely determine the extent to which their use in the classroom will result in improved cognitive achievement. Research stresses the promising potential of computer-assisted learning to bolster student achievement (Roschelle et al., 2016[28]; Pane et al., 2014[29]; Karam et al., 2016[30]; Dinarski et al., 2007[31]). Thus, using ICT for teaching and learning in the classroom does not minimise teachers' role. On the contrary, as the primary actors for implementing the curriculum and orchestrating learning activities, teachers are likely to be even more central to learning with the adoption of ICT. Indeed, the success of using ICT for educational purposes relies heavily on teachers' abilities to select, create and manage adequate digital resources in order to implement innovative and inclusive teaching strategies in a specific context (Redecker, 2017[32]).

Integrating ICT into teaching may lead educators to modify their approach to teaching itself, which would eventually affect students' use of ICT for learning. Some teachers may rely more frequently on specific pedagogical approaches and teaching strategies when using ICT. For example, the ESSIE study shows that teachers using ICT also engage more often in student-centred teaching, although both student-centred and teacher-centred approaches coexist (European Commission, 2013[9]). Teachers may also explore and devise original teaching strategies specifically adapted to ICT. For example, Hennessy, Ruthven and Brindley (2005[33])show that teachers circumvent emerging constraints with ICT by combining ICT resources with other material, or by exploiting ICT possibilities to maintain students' attention on a subject rather than on unimportant features of ICT.

Teachers' pedagogical approaches tend to determine students' use of ICT for learning in the classroom. ICT-based activities in the classroom constitute only one element of the overall teaching strategy. Indeed, teaching with ICT requires particularly careful planning and preparation to select, adapt and create adequate digital resources, and to determine how they are used in teaching and for assessment purposes (Redecker, 2017[32]; Trucano, 2005[34]). Moreover, teachers also support teaching activities by using ICT for communicating and collaborating with their peers, parents and students (European Commission, 2013[9]). While students can report on how digital technologies are used during class, only teachers can provide information on how they prepare to teach with ICT. Consequently, this framework relies on teachers to describe the underlying activities and conceptual approaches of ICT use in the classroom, whereas the diversity of practices and actual uses of ICT for learning are primarily documented through student-reported information.

In this framework, students' use of ICT for learning in the classroom is assumed to be mainly determined by teachers' choice to engage in specific pedagogical approaches. In keeping with previous PISA cycles (and due to the structure of the data collection), teaching strategies will be documented mainly from students' reports and cover pedagogical approaches (applied with or without ICT) as well as ICT-specific practices. Teachers' activities with teaching-related ICT outside the classroom (not observable by students), such as activities related to preparing lessons and assessments, could also be covered through the teacher questionnaire.

In parallel, the framework explores students' use of ICT in the classroom for non-class related purposes. Ubiquitous access to the Internet among students does not only provide a boon to education, it also has its disadvantages. Permanent connectivity can lead students to engage in "distracted use" of ICT resources – constantly checking notifications and website updates, responding to friends' messages, etc. This, in turn, might have substantial negative effects on classroom disciplinary climate and on students' learning outcomes.

Teachers' use of ICT for teaching

In addition to implementing pedagogical practices, teachers' use of ICT for teaching revolves around planning teaching sessions, assessing students, and taking part in supportive communication and collaboration activities with colleagues, parents and students. These activities contribute to the overall effectiveness of ICT use for teaching and are therefore worth documenting.

Teachers spend a substantial amount of time planning and preparing teaching sessions. On average in the countries and economies that participated in the OECD Teaching and Learning International Survey (TALIS) in 2013, lower secondary teachers reported spending seven hours per week planning lessons (OECD, 2014[35]). After a preliminary period of investing time to become acquainted with new practices, ICT might actually help teachers prepare their lessons, regardless of whether ICT-based activities will be conducted during class. For example, teachers can use the Internet and other online applications to find suitable learning resources, or rely on specific software to present certain activities. In this regard, the development of ICT might significantly help teachers renew and adapt learning material and content. In fact, the preparation of teaching activities constitutes the most frequent ICT-based activity conducted by teachers in EU countries, with 30% to 45% (depending on the activity) of students taught by teachers who declare doing this every day, almost every day, or at least once a week (European Commission, 2013[9]).

In addition, teachers face specific challenges when planning to integrate ICT into teaching. Research shows that, without sufficient planning, using ICT may result in a lack of focus among students and lower overall performance (Trucano, 2005[34]). In order to plan lessons involving ICT, teachers must sort through a wealth of ICT educational resources and potentially conduct multiple, time consuming and sometimes complex activities. Indeed, teachers might have to identify, assess and select the ICT resources that best fit their learning objectives, context and pedagogical approach; sometimes, they may even have to adapt or create new digital resources. In parallel, they may also need to manage resources to share them with their students, while maintaining up-to-date knowledge regarding the potential risks involved in sensitive digital content and copyrights (Redecker, 2017[32]). Analysing the time spent on planning lessons and the various types of planning activities teachers engage in could help identify the uses of ICT that are most successful in the classroom.

Teachers also spend a non-negligible amount of time communicating and co-operating with parents and students, in addition to collaborating with teaching staff (OECD, 2014[35]). These activities may enhance the school climate and improve classroom environments (OECD, 2014[35]); they can also provide a way to share good practices for ICT use and ultimately improve student learning. In parallel, ICT may also help disseminate these practices among teachers (European Commission, 2013[9]). By contrary, ICTs could potentially contribute to spreading non-desirable teaching practices.

Indeed, with the widespread availability of computers and Internet access, European schools increasingly communicate with parents through ICT (EACEA, 2011[13]). Communicating with parents (or students) can include disseminating information on the school website and communicating via e-mails or through a dedicated online platform, such as school portals. It can also involve informing parents of their child's progress and difficulties, encouraging parents to help monitor their child's homework, and sharing homework assignments. Similarly, teachers can discuss innovative teaching practices with their colleagues, share and co-create digital resources, monitor students' achievement across subjects or assess their own digital practices and engage in professional development activities.

Teachers' beliefs about the nature of teaching and learning determine their choice of which pedagogical practices to use in the classroom (OECD, 2014[35]). Teachers may believe that active teaching strategies are more efficient and engage students more throughout the learning process. Alternately, they may think that students learn better by finding solutions on their own or that students should learn in groups. Indeed, in TALIS 2013, teachers with constructivist (i.e. student-centred forms of learning) beliefs were more likely to report that students use ICT for projects or class work (OECD, 2014[35]). Teachers also hold beliefs about whether and how to use ICT for teaching and learning. Documenting teachers' beliefs on how teaching should be conducted with ICT would provide insights into the relationship between those beliefs and actual ICT use for learning, as reported by students.

In addition, documenting teachers' reports of whether and how they use ICT in their teaching could be a useful complement to the information (described below) that students report. Teachers could be asked how they share instruction time between structuring practices (i.e. explicitly stating learning goals, summarising previous lessons, reviewing homework and checking student understanding), student-oriented practices (small-group work, ability grouping and student self-evaluation) and enhanced activities (working on projects, making a product, writing an essay and debating arguments) in general, and how the use of ICT may affect their approach. Documenting how ICT affect the time spent on lecturing versus drill and practice activities could also be insightful.

Students' use of ICT for learning in the classroom

Using ICT in the classroom is likely to affect the instruction time and the curriculum to which students are exposed, as well as the teaching and learning processes they experience. These factors have been documented as important predictors of student achievement (Scherff and Piazza, 2008[36]; Schmidt and Maier, 2009[37]; OECD, 2017[4]). Analysing this relationship requires documenting the frequency and modalities of students' use of ICT in relation to existing PISA constructs on learning processes and instruction quality.

In addition to the effect of ICT on instructional time and general learning processes, students' learning outcomes can also be affected by the use of digital educational resources, and original teaching strategies and learning practices with ICT. Given that, existing PISA constructs on instructional quality can be complemented with ICT-specific information. Complementary data on classroom arrangements when ICT are used, and students' opinions of teachers' ICT competencies, can also illustrate the effectiveness of students' use of ICT in the classroom.

Intensity and modalities of students' use of ICT

Many studies have stressed the importance of instruction time as a determinant of student outcomes across various subjects (OECD, 2013[2]). The integration of ICT for teaching and learning can affect instruction time in many ways. Some research shows that teaching with ICT takes more time as it often requires changing the classroom layout and may require frequently altering pedagogical practices (Trucano, 2005[34]). Moreover, when using certain ICT tools, students' attention could be drawn away from learning and they might be tempted to use the ICT resources for leisure activities (e.g. games, browsing the Internet, social media, etc.). Yet ICT-assisted instruction may also increase the overall time students spend learning if, in its absence, teachers must divide their time between group and individual instruction (Bulman and Fairlie, 2016[17]). In this scenario, the ICT resources are expected to take over instruction from the teacher in case of an interruption.[7] Moreover, the modalities of integration of ICT vary across subjects which can lead to disproportionate changes in learning time across subjects.

Therefore, it is important to document not only how frequently students use ICT for learning, but also the length of time that they use ICT in each class, whether they use it continuously or recurrently, and in which classes. Moreover, students can engage with ICT for learning in different ways, which should be accounted for when assessing the intensity of ICT use. Indeed, it may be important to distinguish between situations where students use ICT on their own initiative – to take notes, for example – and learning situations where students use ICT because it is requested by the teacher. In addition, students may not be allowed to use ICT as they desire or, by contrast, might be encouraged to bring their own ICT devices to class. Classroom-level practices regarding students' use of ICT should thus be documented.

A detailed examination of students' ICT use could also document the time spent on, or the frequency with which students use different types of ICT resources. Both the type and the diversity of ICT resources could reveal the degree of complexity of ICT use for learning. In European schools, digital textbooks are the most frequently used resource in grade 8 (with more than 30% of students using them more than once a week), but simulations and data-logging tools are rarely used (European Commission, 2013[9]). Yet the literature emphasises that the latter are more promising for improving student achievement. Using various types of ICT resources, both individually and in combination, could also indirectly indicate more sophisticated teaching approaches and lead to higher cognitive achievement and ICT competencies. The frequency of ICT use could build on the classification of ICT resources developed to measure access to ICT.

Students' use of ICT for non-class-related purposes constitutes an important drawback. A 2015 survey conducted in 26 states in the United States reveals that college students use a digital device around 11 times during a typical school day, on average, for non-class purposes (Mccoy, 2016[38]). Student use ICT for instant messaging and playing games (Barak, Lipson and Lerman, 2006[39]; Driver, 2002[40]), checking e-mail and watching videos (Finn and Inman, 2004[41]), and browsing the Internet and accessing social networks (Tindell and Bohlander, 2012[42]). Many studies highlight the negative effect of so-called "digital distractions" during class on students' learning outcomes, including the ability to take notes, recall detailed information (Kuznekoff and Titsworth, 2013[43]) and comprehend lecture content (Sana, Weston and Cepeda, 2013[44]). Moreover, students' use of ICT for non-class purposes also appears to create distractions for other students who end up with poorer learning outcomes (Tindell and Bohlander, 2012[42]). Thus, students' constant connectivity might contribute to multitasking, which has well-documented effects on attention and the capacity to digest information (Posner, 1982[45]; Pashler, 1994[46]). These studies mainly focus on college students, and the findings may not extend to 15-year-old students who probably face more restrictions regarding ICT use during class. Documenting the types and frequency of students' use of ICT for non-learning purposes, whether they are distracted by other students' activities with ICT, and their attitudes toward these issues thus seems relevant to examining how such experiences affect students' cognitive achievement and well-being.

Teaching and learning with ICT

Based on findings in the literature, the context questionnaires in PISA highlight three dimensions in assessing instructional quality: structure and classroom management, teacher support and student orientation (including scaffolding, students' collaboration techniques, and feedback and assessment mechanisms), and cognitive activation (OECD, 2017[4]). Each of these dimensions has been found to be correlated with students' cognitive achievement (OECD, 2013[2]; OECD, 2017[4]). Each can also be altered significantly by integrating ICT in the classroom (although probably not all to the same extent). Several features of ICT can affect the way teachers provide feedback to students, personalise instruction, develop collaborative projects and rely on group-work assignments. Indeed, findings from previous PISA cycles show that "students using ICT in mathematics class are more likely to describe their teachers as frequently using structuring practices (e.g. setting clear goals, asking questions to verify understanding), student-oriented practices (e.g. giving different work to students who have difficulties or who can advance faster, having students work in small groups), formative assessments (e.g. giving feedback on strengths and weaknesses), and cognitive activation (e.g. giving problems that require students to apply what they have learned to new contexts and/or giving problems that can be solved in several different ways)" (OECD, 2016[3]).

Although students' ICT use in school is positively correlated with effective instructional strategies in PISA, it is not clear how students use ICT for learning and, in particular, whether ICT are used in ways that are related to quality instruction (OECD, 2015[11]). Detailed documentation of whether and how frequently the instructional processes described above actually involve ICT would help fill this knowledge gap. In particular, it could answer a central question regarding the use of ICT in the classroom: do teachers use ICT mainly as a substitute for simple instruction, or do ICT support and enhance the implementation of more complex and valuable learning activities?

While ICT can be used to support or replace more traditional teaching practices, digital learning resources can also transform them. This may occur by creating a new activity or by combining several learning processes and activities. For example, the literature underlines that computer-assisted learning based on (sophisticated) tutoring systems or educational software are more likely to improve students' cognitive achievement (Escueta et al., 2017[18]; Bulman and Fairlie, 2016[17]). These digital learning resources often allow for combining two practices related to personalising education: proposing content and activities tailored to fit the student's learning needs; and providing students (and sometimes teachers) with immediate feedback. Moreover, these tutoring systems also often rely on various forms of digital content, such as videos and simulation tools. The integrated nature of educational ICT resources might constitute an important dimension of their potential success. Documenting this additional aspect of ICT use in the classroom would require developing a careful classification of ICT-specific teaching and learning processes that would account for the possibility of combining practices.

Students' use of ICT may be particularly beneficial for certain tasks or for developing specific skills in a particular subject. It would therefore be interesting to explore the subject-specific dimensions of ICT use. Documenting ICT use in relation to the domains assessed by PISA would be particularly interesting. With the increasing attention given to the acquisition of digital competencies, it would also be useful to document whether specific educational resources (e.g. specific educational software, ICT literacy curriculum, etc.) aim at fostering these competencies.

ICT may also be particularly beneficial to certain students. The development of new digital educational resources can indeed support teachers and education systems to provide inclusive education – that is to support the learning of students with disabilities and special needs in inclusive settings (EADSNE, 2013). Digital learning resources allow disabled and special needs students to take part in learning interactions (e.g. helping a student to write by dictating a text to a special software). They can facilitate communication by providing a new medium (e.g. allowing students with communication disorders to interact in a more convenient way). ICT can also enable teachers to develop personalised learning strategies for students with special needs (e.g. personalised practices and drilling exercises). Moreover, ICT can help students participate in and follow classroom activities from home (or elsewhere) when they cannot attend in person (Unesco, 2011). Enabling environments for teaching and learning with ICT

Teachers' capacity to use ICT resources for teaching and learning depends on several contextual factors and practices, which could be referred to as the enabling environment for ICT use in school. In addition to the quality of access to ICT resources (described in the previous section), enabling factors include contextual information on students' background, school-level policies and practices regarding the governance of ICT use for learning (notably incentives and support for teachers), and teachers' attitudes towards and competencies in using ICT for teaching. The enabling environment partly determines whether and how teachers use ICT resources in the classroom. The adequacy of that environment can be assessed by asking teachers to report the extent to which these factors aid or impede ICT use for learning.

ICT-related practices and policies at the school level

Although numerous aspects related to ICT use in school are decided at the national level, schools often retain some leeway in organising the integration of ICT into teaching. For example, most European schools are responsible for purchasing and maintaining ICT resources in schools, as highlighted in the previous section (European Commission, 2013[9]). School-level governance regarding ICT use for teaching includes consultation mechanisms, guidelines, structures of teacher incentives, and support and practices regarding the assessment and evaluation of ICT use.

The overall school environment, including information sharing, guidance and communication among teaching staff regarding the use of ICT for teaching and learning, constitutes a first important component of school governance. All activities aimed at discussing, consulting, developing a common understanding, spreading information and even communicating guidelines on how ICT should be used for educational purposes in the school are critical to integrating ICT into the classroom. Depending on the school, such activities can differ in their degree of formality and method of delivery (i.e. oral or written ICT guidelines, official directives from education authorities or school-level statements, etc.). Documenting such aspects – for example, by asking teachers or principals whether and how frequently they engage in related activities – can build on the existing framework developed in previous PISA cycles to describe the school climate. In particular, it can explore whether teaching staff share clear norms and attitudes and have mutually supportive interactions regarding ICT use for learning (OECD, 2017[47]).

The use of assessment and evaluation for improving teaching practices constitutes another important element of school governance. The relationship between ICT and evaluation is two-way. ICT can facilitate the implementation of evaluations and assessments in school. For example, principals could rely on online surveys to receive feedback on a specific aspect of the school. At the same time, the practices related to ICT use for learning could be assessed. Both dimensions can be covered by specifying whether the current assessment and evaluation practices rely on ICT, whether new assessment practices were developed based on new ICT, and whether the use of ICT for teaching and learning has been subject to a specific evaluation.

The structure and types of incentives and support teachers can access when using ICT resources for educational purposes are also instrumental in guiding their practices with ICT. Teachers can benefit from training to improve their ICT skills and to develop ICT-specific pedagogical competences. The lack of both technical and pedagogical support was most frequently cited by grade 11 teachers in European schools (European Commission, 2013[9]). Teachers can also benefit from their school's general support policies by having access to manuals and tutorials regarding ICT use, or by taking advantage of the presence of an ICT co-ordinator. The quality of the school environment regarding ICT use should also be assessed by documenting the types of support available to teachers for improving their skills in using ICT. In particular, supporting and assisting teachers' engagement in collaborative teaching experiments and professional development activities promotes change in teaching practices (Ronfeldt et al., 2015[48]; Vieluf et al., 2012[49]).

Support to teachers who use ICT for teaching can also come in the form of incentive or reward programmes. For example, teachers may benefit from financial incentives, career advancement, reduced number of teaching hours, competitions that award prizes, additional training hours and additional ICT equipment for the classroom (Wastiau et al., 2013[50]). Teachers can also become more motivated through informal incentives, such as peer pressure or signals that their overall evaluation may be influenced by their use of ICT in the classroom. However, these incentives may not necessarily be effective in promoting efficient use of ICT and could even crowd out teachers' intrinsic motivation to seize the pedagogical opportunities ICT offer. Documenting existing incentives for teachers to use ICT for learning can provide a more complete picture of the enabling environment in the school.

Teachers' and principals' attitudes and competencies related to ICT

Teachers' use of ICT depends on diverse factors, such as the demographic, social, economic and cultural background of the students, the school climate (truancy, disruptive behaviour), and the level and distribution of students' abilities at the beginning of the school year. All of these factors affect students' learning and teachers' pedagogical approaches. Many of these factors are already accounted for in the general PISA framework. Complementary information specifically relevant to ICT use for learning includes parents' attitudes towards ICT, which have been shown to be significantly associated with ICT use (Brummelhuis and Binda, 2017[51]). Moreover, students' experience and attitudes toward ICT and, in particular, towards using ICT for learning are particularly relevant. These factors are covered, in detail, in the next section.

Principals' and teachers' attitudes towards ICT resources, in general, as well as for teaching and learning are crucial components of the enabling environment. Indeed, in Europe, teachers' positive opinions regarding ICT use for learning is positively correlated with actual use and experience in using ICT (Wastiau et al., 2013[50]). Principals' opinions also matter, as the Second Information and Technology Education Study (SITES) 2006 findings suggest that ICT use by teachers is influenced by the school principal's views about its value (Law, Plomp and Pelgrum, 2006[52]). Measures of teachers' interest in, attitudes towards, motivation and beliefs about ICT and ICT use as a tool for instruction could be developed based on existing PISA constructs on students' attitudes towards ICT use.

In addition, teachers' competencies and experience with ICT also influence their engagement. Teachers' competencies can be approximated by measures of self-efficacy and complemented with factual information about whether they obtained specific qualifications or pursued training to develop their ICT skills and learn how to teach with ICT. Some evidence suggests that new teachers have insufficient training in the pedagogical uses of ICT while more senior teachers may lack technical knowledge in using ICT for learning. Indeed, in TALIS, teachers identify "teaching with ICT" and "using new technologies in the workplace" as the second and third most important professional development needs (OECD, 2014[35]). Moreover, teachers who are more experienced in using ICT for teaching and learning build their self-confidence, which appears to foster greater development of students' skills (OECD, 2014[35]).

Although all of the abovementioned factors contribute to the school environment regarding ICT use for learning, their relative importance is likely to differ substantially across teachers. Documenting the subjective assessment of teachers (or principals) regarding what they consider to be the main obstacles to using ICT in school could yield more insights into these issues. As discussed in the previous section about the obstacles related to the quality of ICT resources, teachers would indicate the extent to which a variety of "enabling factors" encourage or impede the use of ICT.

Students' use of ICT outside the classroom

Over the past decade in PISA-participating countries and economies, the number of 15-year-olds with Internet access has grown, as has the amount of time spent on the Internet outside of school (OECD, 2015[11]). Time spent online increased by about 40 minutes per day between 2012 and 2015, on average across OECD countries, to reach two-and-a-half hours, on average, on weekdays and more than three hours on weekend days (OECD, 2017[47]). With the widespread availability of smartphones, many young people can go on line at virtually any moment. Indeed, a study shows that 24% of 13-17 year-olds in the United States reported going on line "almost constantly" (Pew Research Center, 2015[53]). Moreover, the ESSIE study suggests that most of the time European students spend using ICT is dedicated to leisure activities (European Commission, 2013[9]). These results are in line with the Global Web Index results, which covers over 40 countries. The results recorded an increase, between 2012 and 2016, of around 30 minutes in the average time spent on line, per day, on social media and messaging (GWI, 2017[54]).

Consequently, policy makers are expressing greater interest in understanding how students' engagement with ICT outside the classroom relates to their well-being, cognitive achievement and acquisition of ICT skills. ICT can foster students' engagement and motivation in learning activities outside of school. In particular, students may invest more effort in completing their home assignment when they can use ICT resources. This, in turn can be encouraged by teachers who could adapt home assignments to the possibilities offered by ICT. ICT resources (e.g. school platforms) can also be used to enhance parent and teacher supervision over students' efforts to complete homework.

One of the important advantages of integrating ICT into the education system is bridging the divide between school and home and allowing for more continuity between the two. The increased availability of ICT resources for learning – often designed to capture students' attention and provide an engaging interactive working environment – can also foster students' self-motivated engagement in learning activities. Students can also develop different skills while using ICT for leisure, including problem solving and Internet-safety competencies, and also organisational, networking and communication skills, all of which can contribute to students' cognitive achievement and well-being. However, research has also highlighted several risks associated with misuse or overuse of ICT among young people (OECD, 2017[47]; Hooft Graafland, 2018[55]).

Using ICT for learning

Since teaching and learning is not limited to formal instruction in the classroom, the PISA 2022 questionnaire framework reclassifies students' "after-school" opportunities to learn as an integral part of education (OECD, 2018[56]). ICT can be a catalyst for learning outside the classroom, notably through their potential effect on students' engagement with learning activities and by providing a powerful tracking and monitoring tool for teachers and parents.

Some evidence suggests that digital learning resources may affect students' engagement with and motivation towards learning activities (Faber, Luyten and Visscher, 2017[57]; Hunsu, Adesope and Bayly, 2016[58]; Lazowski and Hulleman, 2016[59]). More specifically, digital formative-assessment tools are likely to enhance students' motivation when the autonomy of the student is also favoured. Positive feedback can increase students' motivation, but negative feedback may have adverse effects on motivation (Muis et al., 2015[60]).

In addition, the development of a wealth of digital learning resources, providing students with more and better learning opportunities, such as educational games, Massive Online Open Courses (MOOCs), and a variety of topic–specific media content, such as video and audio podcasts, tutorials, etc., may spark students' interest in using ICT for learning outside the classroom. The availability of such resources for free might be particularly helpful for disadvantaged students who now face fewer barriers to e-learning and a wide range of learning content (UNICEF, 2017[61]). In addition, teachers may take advantage of students' interest in ICT by assigning homework that requires the use of ICT. Moreover, students' interest in ICT may encourage them to engage in informal learning activities about ICT itself such as following coding classes and participating in programming clubs.

ICT can also be used as a tool to foster communication between schools and students (or parents) and monitor students' achievement and efforts. Research shows that behavioural interventions aimed at improving information flows between the school and parents and, in particular, encouraging parental engagement in learning activities with their children could ultimately help improve students' education outcomes (Levine et al., 2010[62]; Senechal and LeFevre, 2002[63]). Moreover, since parental engagement is particularly poor among socio-economically disadvantaged students, strengthening school-parent communication through the use of ICT can help reduce, or at least not increase, disparities in education outcomes related to parental engagement (Escueta et al., 2017[18]). ICT may also allow teachers to track students' completion of homework assignments, which could prompt stronger engagement with learning activities.

Using ICT for leisure

Most of the time students spend using ICT outside the classroom is dedicated to leisure activities. Over the past two decades, ICT have not only transformed how 15-year-olds learn, but also how they socialise and play (OECD, 2015[11]). Access to the Internet is now almost universal. Students use the Internet daily, and most digital activities for leisure happen on line.

The evolution of ICT practices can be observed in the PISA data. Between 2009 and 2012, e-mail and chat use have declined, likely due to the emergence of new forms of communication, such as social networking and other web-based messaging tools. Similarly, students' use of one-player games seems to have been replaced by online collaborative games (OECD, 2015[11]). The rapid changes in students' habits and practices regarding ICT use for leisure should be carefully documented to examine how these activities can contribute to – or impede – students' cognitive performance and their acquisition of ICT competencies.

The extent to which ICT use for leisure is potentially related to students' cognitive performance, ICT skills and well-being depends on the frequency, the diversity and the type of activities students engage in (van Deursen and Helsper, 2015[64]). The main challenge with documenting ICT use for leisure is to ensure enough continuity across PISA cycles and comparability across countries and economies, while expanding and transforming the coverage to capture new forms of ICT engagement. Certain activities covered in the current PISA framework are obsolete and should probably be grouped together or replaced (e.g. using e-mail and chatting on line). Conversely, some ICT resources have become more central to students' lives and can be used in a variety of ways. These should be identified distinctly. For example, there are various ways of "participating in social networks", with very different implications on students' outcomes.

ICT use for leisure provides an opportunity for students to acquire ICT knowledge and skills. One way to capture the diversity of ICT use for leisure in a relatively stable and relevant manner would be to link each activity to a specific competency area identified in ICT/digital literacy frameworks. These competency areas differ across frameworks, yet they all involve accessing, evaluating and managing information; transforming, creating and sharing information; communicating; using information safely, ethically and securely; and demonstrating a general understanding of ICT use (Fraillon, Schulz and Ainley, 2013[1]; Carretero, Vuorikari and Punie, 2017[6]; Fraillon et al., 2015[5]; ICT Literacy Panel, 2002[65]). While these competency areas define ICT literacy, many are specifically relevant to cognitive achievement in mathematics, science and reading. Using information safely, ethically and securely might be particularly important for students' well-being.

As mentioned earlier, students' use of ICT for leisure also involves risks, and is a source of concern among parents and policy makers (Hooft Graafland, 2018[55]). Inappropriate or unsafe Internet use can expose students to harmful content or to cyberbullying. For example, the EU Kids Online survey shows that 21% of 11-16 year-olds from 25 European countries have encountered one or more websites with potentially harmful user-generated content, including hate messages (12%), pro-eating disorder sites (10%), selfharm sites (7%), pro-drug-taking sites (7%) and suicide sites (5%) (Livingstone et al., 2009[66]). In the United States, 41% of adults have been personally subjected to harassment on line; and a quarter of 18-29 year-olds have experienced mental or emotional stress as a result of online harassment (Dragiewicz et al., 2018[67]). Students also face an enormous amount of information online that might help them develop online reading skills, but can also have negative implications if the students are not able to distinguish fact from fiction and verify online sources. For instance, a recent study focusing on Italy shows that only 42% of 9-17 year-old Italians report finding it easy to check if online information is true (Mascheroni and Ólafsson, 2018[68]).

Additional risks, such as overuse of video games and compulsive use of social media, can have serious physical, social, psychological and cognitive consequences (OECD, 2017[47]; Smith et al., 2008[69]; Currie et al., 2012[70]). These risks are real and are not restricted to a minority of students. Nowadays, the vast majority of adolescents have access to ICT resources in their bedrooms. The National Sleep Foundation revealed that more than three in four 13-18 year-olds in the United States sleep with their cell phone next to their beds, and more than one in two report sending text messages in the hour before trying to go to sleep every night or almost every night (National Sleep Foundation, 2011[71]).

Therefore, in addition to the environmental factors covered above, risky behaviours and modes of ICT use should be documented. This could, for example, aim to identify compulsive and addictive use of ICT, whether students are mostly passive or active on line and whether they follow routines when they use the Internet. Information could also be collected about what students consider to be acceptable and ethical use of social media.

The environment for ICT use outside the classroom

As with ICT use in the classroom, several contextual factors, policies and practices influence ICT use outside the classroom. The quality and modalities of access to ICT resources outside the classroom, which can be described along the dimensions of availability, accessibility and quality of ICT resources (see Section 3), largely shape students' use of ICT. Moreover, students' use of ICT in the classroom can influence how these resources are used outside the classroom (and vice versa), notably by exploring new practices and the acquisition of ICT competencies, including awareness of the different risks related to ICT use. Schools also play an important role in providing information and training to parents regarding online safety and effective Internet use (Hooft Graafland, 2018[55]). In addition, students' attitudes towards ICT use for learning and for leisure (covered in the next section) guide students' use of ICT outside the classroom.

The framework refers to students' use of ICT outside the classroom and not at home because, in some cases, students' main access to ICT outside the classroom might not be at home but in other locations, such as in libraries, computer labs, etc. The regulatory environments in these different locations can be documented in a comparable way. Yet for reasons of comparability and simplicity, it may be more relevant to focus only on the regulatory environment at home.

Research shows that the regulatory environment can influence students' use of ICT outside the classroom and, consequently, students' education outcomes. For instance, in Romania, there is evidence suggesting that the negative effect on students' grades from providing subsidies to households to purchase computers was reduced when parents provided more structure and guidance on how and when to use ICT (Malamud and Pop-Eleches, 2011[20]). This suggests exploring a set of practices that limit, to some extent, students' liberty in using ICT. Such practices include imposing a time limit or deadline on using some ICT resources, requiring parents' authorisation to use the ICT resources, or using parental control software. Practices related to parental guidance should also be covered.

Students' cognitive and well-being outcomes

This framework aims to assess the relationship between students' access to and use of ICT with three distinct outcomes: students' cognitive achievement, students' well-being and students' competencies in ICT. This framework relies entirely on existing PISA frameworks to measure students' cognitive achievement in mathematics, science and reading, as well as their well-being. It also proposes an approach to assessing students' competencies in ICT, which are defined here in a broad sense that encompasses digital literacy as a specific domain as well as students' attitudes and dispositions towards ICT use in various contexts. While proposing a fully-fledged assessment framework for digital (or ICT) literacy is beyond the scope of this framework, a roadmap for such a framework is suggested for future PISA assessments.

Students' cognitive achievement and well-being

PISA's approach to measuring students' cognitive achievement consists "in assessing not only whether students can reproduce knowledge, but also whether they can extrapolate from what they have learned and apply their knowledge in new situations. It emphasises the mastery of processes, the understanding of concepts, and the ability to function in various types of situations" (OECD, 2017[4]). Thus, rather than assessing mathematics, science and reading per se, PISA aims at documenting mathematics literacy, science literacy and reading literacy, where literacy refers to "students' capacity to apply knowledge and skills in key subjects, and to analyse, reason and communicate effectively as they identify, interpret and solve problems in a variety of situations" (OECD, 2017[4]). For simplicity, the following refers simply to mathematics, science and reading assessment frameworks.

This section summarises the most recent assessment framework for each domain, which is revised every nine years (three cycles) when it becomes the main domain of PISA. Thus, the assessment framework for mathematics was revised for PISA 2022, while the reading framework was revised in 2018 and science was revised in 2015. This section also presents the framework to assess adolescents' well-being, which was developed for PISA 2018.

Assessing mathematical literacy in PISA

Preliminary work for the (to-be revised) PISA 2022 mathematics framework defines mathematical literacy as "an individual's capacity to reason mathematically and to formulate, employ, and interpret mathematics to solve problems in a variety of real-world contexts. It includes concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to know the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective 21st-century citizens" (OECD, 2018[56]). The assessment of mathematical literacy is organised around three interrelated aspects presented in detail below: mathematical reasoning and mathematical processes, the mathematical content and the context of the assessment, including its relation to 21st-century skills.

Mathematical reasoning contributes to individuals' ability to reason logically and to present honest and convincing arguments. Mathematical reasoning comprises a few "big mathematical ideas" that can be seen as the core of mathematical literacy. These ideas include: quantity; number systems and their algebraic properties; mathematics as a system based on abstraction and symbolic representation; mathematical structure and its regularities; functional relationships between quantities; mathematical modelling as a lens onto the real world (e.g. onto the physical, biological, social, economic and behavioural sciences); and variance as the heart of statistics (OECD, 2018[56]).

Mathematical literacy is organised and structured around three major mathematical processes (or, in the terminology of PISA 2022, problem-solving processes). They describe what individuals do to connect the context of a problem with the mathematics that is entailed, thereby solving the problem:

- **Formulating situations mathematically** refers to individuals' ability to recognise and identify opportunities to use mathematics and to translate a problem presented in a real-world context into mathematical terms and structure.
- **Employing mathematical concepts, facts, procedures and reasoning** corresponds to individuals' capacity to apply mathematics to solve mathematically-formulated problems and obtain mathematical conclusions.
- **Interpreting, applying and evaluating mathematical outcomes** focuses on individuals' ability to reflect upon mathematical conclusions and interpret them in the context of the real-life problem. This involves translating mathematical solutions back into the context of the problem and making sense of the conclusions.

The assessment of mathematics is organised around content knowledge categories that reflect both the mathematical phenomena that underlie the general structure of mathematics as well as the major strands of typical school curricula. The content categories used in PISA 2012 and that will again be used in PISA 2022 are change and relationships, space and shape, quantity, and uncertainty and data (OECD, 2018[56]; 2013[2]). Within each of these categories, special emphasis will be given to a specific topic that reflects the type of mathematics needed to understand emerging areas of society and economy in the 21st-century. These topics are growth phenomena, geometric approximation, computer simulations, and conditional decision making.

An important feature of mathematical literacy, as defined in PISA, is that mathematics is used to solve a problem set in a real-world context and/or to help 21st-century citizens make informed decisions. A wide variety of contexts should be used to connect with a broad range of students' interests across PISA-participating countries and economies. The following context categories will be used to develop items for PISA 2022:

- **personal**, which focuses on one's own activities or those of one's peer group such as food preparation, shopping, games or personal transportation
- **occupational**, which is centred on the world of work and includes problems such as measuring, costing and ordering material for building, accounting, quality control, design and job-related decision making
- **societal**, which refers to problems of one's community and includes problems related to voting systems, public transport, government and economics, among others
- **scientific**, which relates to the application of mathematics to the natural world and issues related to science and technology including topics such as climate, ecology and medicine but also relates to the world of mathematics itself when all the elements included belong to the mathematical context.

The assessment of mathematics in PISA 2022 includes developments that are of particular interest for this framework, notably in relation to ICT literacy. In order to reflect the growing role of technology in students' lives and to explore increasingly sought-after competencies, the mathematical literacy assessment has put more emphasis on computational thinking. In this context, computational thinking refers to formulating problems and designing their solutions in a form that can be executed by or with a computer (Cuny, Snyder and Wing, 2010[72]). In addition, the PISA 2022 assessment framework identifies critical thinking, creativity, research and inquiry, self-direction, initiative and persistence, information use, systems thinking, communication and reflection as critical 21st-century skills to be included in the assessment of mathematics (OECD, 2018[56]).

Assessing reading literacy in PISA

Starting in PISA 2018, reading literacy has been defined as “understanding, using, evaluating, reflecting on and engaging with texts in order to achieve one’s goals, to develop one’s knowledge and potential and to participate in society”. The definition has evolved over time to reflect the increasing importance of information technology in citizens’ social and work lives. Hence, reading literacy no longer predominantly focuses on the ability to understand, interpret and reflect upon single texts, but reflects a broader range of skills, including higher-level digital reading skills (OECD, 2016[3]).

Following Snow and the RAND group’s (2002) influential framework, reading is considered as the joint outcome of three components: the reader, the text and the task. Reader factors include motivation, prior knowledge and other cognitive abilities. Text factors relate to, among other things, the format, level of difficulty, type of language and number of pieces of text encountered. Task factors correspond to the requirements or reasons that motivate the reader’s engagement with the pieces of text, including time and other practical constraints, the objectives of reading (e.g. for pleasure, for deep understanding or for a cursory overview), and the complexity or number of tasks. The combination of these factors determines how readers apply reading processes in order to locate and extract information and to construct meaning from texts in order to fulfil their tasks (OECD, 2016[3]).

In order to adequately assess the many facets of reading – a pervasive and highly diverse activity – it is necessary to ensure a broad coverage of what students read, for what purposes they read and in which context they read. Thus, the PISA reading assessment relies on variation in the range of material that is read; in the reading processes, or the cognitive approach that determines how readers engage with a text; and in the reading scenarios – the range of broad contexts in which or purposes for which reading takes place.

In PISA 2018, the typology of reading processes identifies reading fluently as a process distinct from the other cognitive processes related to text comprehension (locating information, understanding, and evaluating and reflecting). Reading fluently is the ability to read accurately and automatically in order to comprehend the overall meaning of the text. Locating information includes accessing and retrieving information within a piece of text and searching for and selecting relevant texts. Following Kintsch’s definition of a “situation model” (1998[73]), two core processes contribute to the process of understanding a text: constructing a representation of the literal meaning of the text and generating an integrated text representation, which requires connecting the text with one’s prior knowledge. Finally, the evaluating and reflecting process requires readers to reflect on the content and form of the text, critically assess the quality and validity of information, and deal with contradictions and conflicts within and across texts (OECD, 2016[3]).

Assessing science literacy in PISA

The PISA 2015 assessment and analytical framework defines scientific literacy as “the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen”. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies of explaining phenomena scientifically, evaluating and designing scientific enquiry, and interpreting data and evidence scientifically (OECD, 2017[47]).

The assessment of students’ performance in science covers four aspects: contexts, knowledge, competencies and attitudes. Contexts refer to a set of personal, local and global issues that demand some understanding of science and technology such as health and disease, natural resources and the environment. Knowledge corresponds to the understanding of the main facts, concepts and theories that form the basis of scientific knowledge; specifically, it includes content knowledge, procedural knowledge and epistemic knowledge. Competencies are the ability to explain scientific phenomena, evaluate and design scientific enquiry, and interpret data and evidence scientifically. Finally, attitudes toward science refer to students' interest in science and technology, how they value the scientific approach and their perception and awareness of environment issues (OECD, 2017[4]).

Assessing adolescents' well-being in PISA

Adolescents' well-being can be defined as the quality of students' lives and their standards of living. There seems to be a consensus that well-being is a multi-dimensional construct with both objective material components and subjective psychological facets. The PISA 2018 framework for the assessment of well-being integrates these different perspectives. In addition to students' overall perceived quality of life or life satisfaction, the framework covers three other dimensions of well-being, each of which incorporates both objective and subjective components: self-related well-being, well-being in school environments and well-being outside of school environments (OECD, 2016[3]).

Overall life satisfaction is a core dimension of subjective well-being. Two alternative approaches are widely used to assess life satisfaction: an evaluative approach, where individuals evaluate their lives, and a life satisfaction approach, where individuals respond to questions such as "How satisfied are you with your life overall these days?" Although the two approaches are very similar, the life satisfaction approach is preferred in PISA as it is simpler to administer and less intrusive (OECD, 2015).

Self-related well-being focuses on "how fit and healthy students are and how they feel about themselves and their lives" (OECD, 2016). It is divided into three sub-dimensions:

- **Health**, which can be documented by objective indicators such as the body mass index, physical exercise, typical sleep duration and risky behaviours; and subjective indicators including perception of and satisfaction with body image, satisfaction with sleep, and satisfaction with and perceived overall health
- **Education and skills**, which also includes students' perceptions of their ability to perform specific tasks and their overall confidence in their own abilities; the assessment of cognitive achievement in PISA provides objective indicators, while self-efficacy measures and questions on students' satisfaction with their knowledge and skills provide subjective indicators
- **Psychological functioning**, which relates to one's sense of meaning, purpose and engagement, and is referred to as "eudaimonic well-being" in the literature (OECD, 2016[3]). The OECD guidelines on measuring subjective well-being identify three main facets of eudaimonic well-being: competence, autonomy and meaning (or purpose), and optimism.

The second dimension of well-being covered in the framework relates to students' quality of life in their school environment. Adolescents spend a large amount of time at school and their experiences and relationships at school are strongly correlated with their perceived quality of life (OECD, 2016[3]). Two main sub-dimensions of school-related well-being are explored:

- **Social connections** include social relationships with teachers and other students, and general patterns of students' interactions that might foster a sense of belonging at school (OECD, 2016[3]). Objective indicators include whether students experienced bullying, while subjective indicators include student-teacher relationships, the school climate, a sense of belonging, perceived discrimination and social connectedness.
- **Schoolwork**, which refers to students' workload and time spent at school, also contributes substantially to students' well-being. For example, extreme hours of schooling or an overload of homework can lead to stress and health-compromising behaviours (OECD, 2016[3]). Objective measures of the level of schoolwork include the total time students spend at school, commuting and doing homework. Subjective indicators include, for example, the emotions experienced (both positive and negative) during selected episodes associated with schoolwork.

Well-being in out-of-school environments can be broken down into three components:

- **Social connections** outside of school, which refer mainly to students' friendships and their relationships with their parents. Studies suggest that family relationships and friendships are the main factors that determinate self-satisfaction (Edwards and Lopez, 2006[74]; Suldo et al., 2014[75]). Social connections can be documented with objective indicators, such as time spent on activities with friends, and with subjective indictors, such as students' perceptions of and satisfaction with their social connections (e.g. their satisfaction with their number of friends, the degree to which they feel they have fun with their friends, and the degree to which they feel that they are treated fairly by their parents) (OECD, 2016[3]).
- **Material living conditions** are measured objectively through the PISA index of economic, social and cultural status (ESCS), which is itself derived from questions in the student questionnaire on home possessions, parents' education and parents' occupation. Research suggests that perceived social and economic standing could be even more crucial in determining individuals' well-being (OECD, 2016[3]). Thus, subjective indicators about perceived poverty and perceived aspirations failure could be collected.
- **Leisure time**, when students can engage and flourish in self-chosen activities. Objective indicators of leisure time include the total time available for such activities and the activities that students engage in. Subjective indicators could include both the positive and negative affective and emotional states of students during leisure time.

Students' competencies in ICT: Digital literacy, and attitudes and dispositions towards ICT

As indicated by the hundreds of digital literacy initiatives around the world, ensuring that students acquire sufficient ICT competencies is becoming an increasingly important objective for policy makers and education systems (Melorose, Perroy and Careas, 2008[76]). ICT competencies are not only valuable for their capacity to support teaching and learning, but also as an independent area of focus, as those skills have become essential for participating fully in the digital age.

In line with previous PISA cycles, this framework takes a broad perspective on ICT competencies, which include the set of knowledge, understanding, attitudes, dispositions, and skills necessary to thrive in the digital age. Indeed, the attainment of knowledge and skills in a specific area is intricately intertwined with individual attitudes and dispositions towards learning. On the one hand, research shows that attitudes and dispositions are central to the learning process, and contribute to individual development and well-being ((European Commission, 2013[9]; Almlund et al., 2011[77]; Heckman, Stixrud and Urzua, 2006[78]). On the other hand, they may also be considered as education outcomes in their own right (Bertling, Borgonovi and Almonte, 2016[79]).

Students' attitudes and dispositions towards ICT are therefore considered as parts of ICT competencies in this framework. Indeed, students' motivation to learn ICT-related skills, their openness to new experiences, willingness to collaborate and engage with others using ICT, and their confidence in conducting certain tasks with ICT are strong determinants of their level of proficiency with ICT and their ability to use them for learning. As teaching and learning tools, ICT can also affect students' attitudes and dispositions towards learning in general.

Governments and policy makers are increasingly interested in assessing students' levels of proficiency in ICT. This framework proposes a direction that the assessment of ICT literacy could take in future PISA cycles even though a complete assessment of ICT literacy is beyond its scope. Yet, this framework documents specific dimensions of students' ICT competencies relying on measures of self-efficacy, attitudes and dispositions towards using ICT in various contexts.

Students' digital literacy

The growing importance of students' ICT literacy for policy makers and education systems is reflected in the frequent inclusion of a variety of ICT competencies in curricula (European Commission, 2013[9]). Interestingly, as measures of ICT competencies become more widely recognised, education systems tend to shift from teaching ICT skills in isolation towards a more horizontal approach, integrating specific ICT tasks and competencies across subjects (European Commission, 2013[9]). This highlights the cross-cutting and complex nature of ICT, which are often used as a tool to support instruction, but are also recognised as a subject of learning in themselves.

Although this framework does not provide a full-fledged assessment of ICT competencies, it proposes foundations for integrating ICT literacy as a specific domain in future PISA cycles. It relies on existing assessments of ICT literacy to identify the main methodological challenges and key competency areas that should guide the development of such assessment.

Competence framework for ICT literacy

This framework proposes measuring students' competencies in ICT as a stand-alone discipline, independent of using ICT for enhancing the teaching and learning of specific subjects. This contrasts with assessments previously conducted in PISA, notably that of digital reading literacy, which combines the assessment of subject-specific achievement and ICT use, and therefore implicitly assumes they are inter-related (European Commission, 2013[9]). In such assessments, the ICT resource is considered as "a vehicle for students to express their discipline-specific knowledge, understanding, and skills" (European Commission, 2013[9]). By contrast, assessing ICT literacy as a specific domain recognises the importance of being able to conduct a variety of more or less complex tasks related to information processing in various digital contexts. It also facilitates comparisons across countries as the assessment is not anchored in a specific learning area or content.

The Feasibility Study for the PISA ICT Literacy Assessment defines ICT literacy as "the interest, attitude, and ability of individuals to appropriately use digital technology and communication tools to access, manage, integrate, and evaluate information, construct new knowledge, and communicate with others in order to participate effectively in society" (Lennon et al., 2003[80]). This definition shares many similarities with the approach developed in other ICT literacy assessment framework such as ICILS and Australian Curriculum, Assessment and Reporting Authority (ACARA) ICT Literacy among others (Fraillon et al., 2015[5]; 2013[1]). In particular, these definitions draw extensively upon information literacy, they assume that individuals possess the technical skills required to effectively use digital technologies, they identify similar sets of processes and they recognise ICT literacy as a requirement for individuals to fully participate in 21st-century society.

In light of the growing importance of digital businesses in the global economy and increasing work opportunities available in "big data" and "artificial intelligence", for example, many countries show a burgeoning interest in including computational thinking, problem solving, data literacy and other 21st-century skills in their curricula. Recent assessment frameworks for ICT literacy reflect this evolution, and give more weight to computer literacy, data literacy and critical thinking. Thus, DigComp 2.1 makes explicit reference not only to information but also to data literacy, and includes problem solving as a key competency area (Carretero, Vuorikari and Punie, 2017[6]). Moreover, the International Computer and Information Literacy Study ICILS 2018 extends the computer and information literacy construct to include a new computational thinking strand (IEA, 2017[81]).

A comprehensive framework to assess ICT competencies could therefore revolve around five main competency areas, namely accessing, evaluating and managing information and data; sharing information and communicating; transforming and creating digital content; individual and collaborative problem solving in a digital context, and computational thinking; and appropriate use of ICT, which embeds knowledge and skills related to security, safety and risk awareness (Fraillon et al., 2015[5]; Fraillon, Schulz and Ainley, 2013[1]; Redecker, 2017[32]).

Competency area 1: Accessing, evaluating and managing information and data

Accessing information and data focuses on the extent to which individuals can identify the desired information, data or digital content and understand how to find and recover computer-based information from various sources, by using ICT (Fraillon et al., 2015[5]; ACARA, 2015[82]).

Evaluating information and data is an integral step in accessing information and ever more so with the development of search engines and artificial intelligence. This involves the process of filtering through multiple information sources, and assessing their relevance, integrity and usefulness (Fraillon, Schulz and Ainley, 2013[1]; ACARA, 2015[82]). As growing amounts of data, news and reports are communicated through the Internet, the process of sorting through all this information is becoming increasingly essential for users. Evaluating information successfully requires critical thinking and may include the ability to verify the credibility of various news sources, or the capacity to comprehend and isolate the necessary data for a specific task, for example.

Managing information and data refers to the ability to organise and store various types of digital information (ACARA, 2015[82]).It involves the ability to adopt and develop systems for organising and classifying information in such a way that the information can be retrieved and reused efficiently (Fraillon, Schulz and Ainley, 2013[1]). Managing information successfully requires understanding the properties of different organisational structures in relation to the way in which the information will be used eventually. This component incorporates policies and procedures for centrally managing and sharing information among different individuals, organisations and information systems.

Competency area 2: Sharing information and communicating

Sharing information and communicating refers to one's ability to exchange information, share knowledge, and customise such communication for a specific audience, context and medium (Fraillon, Schulz and Ainley, 2013[1]; ACARA, 2015[82]). This includes detailed knowledge regarding the real and digital contexts in which information are shared and to whom and thus require awareness about the specificities of ICT-based communication platforms available, including e-mail, instant messaging and group chat, media sharing and social-networking websites, among others. Given the wide range of use of ICT for communication, effective communication would require a thorough understanding of information-based social conventions, and the ability to adapt and modify selected modes of communication for the intended recipient(s).

Competency area 3: Transforming and creating information and digital content

Transforming and creating information involves the use of ICT and ICT-based data, digital content and information to develop new information or knowledge. Successful individuals can take existing information and derive new understandings by adapting, applying, designing, inventing or authoring (Fraillon, Schulz and Ainley, 2013[1]). Individuals may transform information with ICT, either to produce or expand upon existing information, by modifying its presentation for improved understanding in specific contexts. This process often requires the ability to use ICT-based formatting, graphics and multimedia to simplify and enhance the communication of information. Information transformation and creation are also related to the quality of information, specifically with regards to how structure, layout and design are used to support overall comprehension.

Competency area 4: Problem-solving in a digital context and computational thinking

PISA 2012 defines problem solving as individuals' capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen (OECD, 2013[2]). In the context of ICT literacy, the focus should be on solving technical problems, identifying technical responses and solutions and creatively using digital technologies to solve a problem. The main cognitive processes involved when solving a problem individually include exploring a problem situation (e.g. observing and interacting with the situation and searching for information, limitations and obstacles) and understanding the information and relevant concepts, representing and formulating (which refers to building a coherent mental representation and hypotheses), planning and executing (which consists of setting goals, devising and strategy and carrying it out), and finally monitoring progress and reflecting on solutions (OECD, 2013[2]).

Following PISA 2015, collaborative problem-solving competency can be defined as "an individual capacity to engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge skills and efforts to reach that solution" (OECD, 2017[4]). Collaborative problem solving is particularly relevant in the context of ICT not only because digital technologies have multiplied collaborative possibilities in society and work settings but also because the digital economy is in many regards also a collaborative economy that would benefit from people's and institutions' abilities to collaborate. Collaborative problem solving in a digital environment includes the cognitive components of individual problem solving but requires additional cognitive, social and technical skills to ensure a shared understanding and information flow, to appropriately use digital resources in order to create and understand an appropriate team organisation, and to perform co-ordinated actions to solve the problem (OECD, 2017[4]).

According to ICILS 2018, computational thinking can be defined as the "ability to identify a problem, break it down into manageable steps, work out the important details or patterns, shape possible solutions and present these solutions in a way that a computer, human or both can understand" (IEA, 2017[81]). Although computational thinking and problem solving in a digital environment strongly overlap and share many thoughts processes, one key difference can be that computational thinking focuses on how to rely on digital and computing possibilities to solve problems and carry out solutions. Indeed, a recent study highlights that "computational thinking is a problem solving methodology that expands the realm of computer science into all disciplines, providing a distinct means of analysing and developing solutions to problems that can be solved computationally" (ACM et al., 2016[83]). According to the Computer Science Teachers Association (CSTA) and the International Society for Technology in Education, the assessment of computational thinking could focus on the following key processes (Bocconi et al., 2016[84]):

- "formulating problems in a way that enables us to use a computer and other tools to help solve them
- logically organizing and analysing data
- representing data through abstractions such as models and simulations
- automating solutions through algorithmic thinking (a series of ordered steps)
- identifying, analysing and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
- generalising and transferring this problem-solving process to a wide variety of problems."

Competency area 5: Appropriate use of ICT (online security, safety and risk awareness and skills)

Online safety and security issues incorporate the appropriate use of ICT across multiple contexts and platforms. Using ICT appropriately requires making critical and thorough assessments of ICT use while considering the social, legal and ethical issues in different settings (Fraillon et al., 2015[5]). With increased information sharing, students must be aware of methods for handling and protecting personal information. Basic knowledge of security, including the use of strong passwords, preventative measures against viruses and protection of private information, partially overlaps with technical ICT skills.

The interest of policy makers in assessing students' safety and security competencies in ICT is reflected in the wide inclusion of such competencies in school curricula across education systems (EC, 2013). As ICT use in and outside of the classroom becomes more common, a wide variety of online safety issues is being included in school curricula. These online safety courses have covered a variety of topics, including safe online behaviour, privacy, cyberbullying, downloading, copyright, safe use of mobile phones, and contact with strangers (EACEA, 2011[13]). This trend emphasises the growing importance of integrating online safety and security practices with ICT instruction, in addition to understanding existing knowledge of safety and security issues regarding ICT access and use.

Students' attitudes and dispositions towards ICT

The assessment of students' (and potentially parents') ICT-related attitudes and dispositions rely extensively on existing measures developed for previous PISA cycles. More precisely, it follows the PISA 2022 taxonomy, which revolves around six dimensions: attitudes; values and beliefs; task performance; emotional regulation; collaboration; and open-mindedness and engagement with others. It also includes one compound construct that draws on several aspects of the different dimensions (OECD, 2018b).

Although all dimensions listed above are not equally relevant to ICT, they are related to ICT literacy in two different ways. First, students' attitudes, behaviours, beliefs and aspirations related to ICT are likely to be correlated with ICT literacy and students' ability to use ICT for learning and leisure. This suggests exploring how students feel or behave when using ICT in general, but also when using ICT in specific contexts, including learning and leisure.

Second, the use of ICT for teaching and learning can alter students' attitudes and dispositions towards learning in general or for a specific subject. This is often one of the reasons why ICT are used for learning. These two relationships between students' ICT use, and attitudes and dispositions are investigated in the following ways:

Self-efficacy refers to students' beliefs regarding their ability to execute a specific task or to achieve a given goal. A related construct is self-concept, which corresponds to students' global judgement of how they perceive their abilities in relation to a particular domain. Research suggests that higher levels of ICT self-efficacy are associated with higher levels of learning outcomes (Fraillon et al., 2014[85]). In the absence of a proper assessment of ICT competencies, self-efficacy constitutes the primary source of information about students' ICT skills. It would therefore be of great value to ask students to evaluate their abilities based on a set of tasks and situations that reflect the five competency areas mentioned above: accessing, evaluating and managing information and data, sharing information and communicating, transforming and creating digital content, problem solving and computational thinking, and knowledge, skills and behaviours related to online security, safety and risks.

Interest, enjoyment and intrinsic motivation in a particular subject are shown to be positively correlated with learners' achievement in general. Results from the International Computer and Information Literacy Study (ICILS) 2013 suggest similar conclusions for ICT. Indeed, ICILS 2013 reveals positive associations between students' interest and enjoyment in working with computers and ICT literacy (Fraillon et al., 2014[85]). Students' interest and motivation should be assessed with reference to a set of tasks representing different levels and types of competences with ICT.

In parallel, research suggests that ICT use in the classroom can also affect students' motivation and interest in learning a specific subject (Lajoie and Azevedo, 2015[86]). This suggests that students' abilities to use ICT for learning can be measured by assessing students' motivation and interest, when confronted with a set of ICT-based tasks, related to a given subject (i.e. mathematics, reading and science).

Emotional regulation and task performance cover aspects of students' emotions and emotional control (i.e. their capacity to curb anxiety, handle stress, develop and maintain positive expectations, etc.), and aspects related to students' diligence and commitment, including setting high standards, working hard and avoiding distractions (Kankaraš and Suarez-Alvarez, 2019[87]). Knowing whether students are anxious or stressed when using ICT, and whether they are committed to understanding how to conduct specific tasks with ICT in different contexts would provide insights into their abilities to use ICT, particularly for learning purposes. It would also be interesting to document whether students' emotional control and subject-specific task performance change when using ICT resources for learning. This might require the inclusion of ICT-based tasks for a specific subject, for example.

In addition, emotional regulation and task performance could be developed to document students' potentially risky behaviours with ICT. Notably, aspects related to students' self-control, dependence and abilities to regulate their engagement in specific ICT activities would reveal students' capacity to cope with addiction and overuse of ICT. This could be complemented by measures of students' perceptions about responsible use of ICT, as well as their sense of responsibility and awareness of security with regards to digital content and practices.

Collaboration, open-mindedness and students' engagement with others cover students' approaches to connecting with other people and the perceived value of those connections; openness to new experiences, perspectives and eagerness to learn and experience; and enjoyment of social connections and assertiveness in voicing their own views (OECD, 2018[56]). Many of these aspects are particularly relevant to the context of ICT use for learning in the classroom. Indeed, documenting students' approaches toward collaboration with peers to solve problems using ICT resources, or collecting information on students' willingness to engage in enquiry-based learning activities with ICT, would provide useful information on students' "readiness" to use ICT. Moreover, measures of students' open-mindedness and extraversion can help document their use of ICT for leisure and, in particular, social media. For example, students' interactions with peers on social networks, as well as their abilities to voice and consider opposing views could identify students' social inclusion and well-being.

Metacognition refers to students' knowledge of learning strategies for a specific subject. For example, metacognition in reading refers to students' awareness and ability to use a variety of appropriate strategies when processing texts in a goal-oriented manner (OECD, 2009[88]). Metacognitive reading strategies have been positively associated with students' reading proficiency (Waters and Schneider, 2010[89]; OECD, 2017[4]). When ICT serves as a mean to learn reading, science or mathematics, students face new learning strategies and practices. Thus, it seems important to document students' awareness about the effectiveness of ICT-based learning strategies. Indeed, metacognition appears to be even more important for digital reading literacy that requires "efficient and specific self-regulated strategies" (Coiro, Julie and Dobler, Elizabeth, 2007[90]). In light of the analogies between ICT literacy and reading literacy, which are both a means to deliver instruction and an end in themselves, it seems promising to document metacognition in ICT literacy itself, focusing on students' understanding and awareness when learning ICT skills.

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Notes

[1] The framework distinguishes between student use of ICT resources during classroom lessons (and therefore under the supervision of at least one teacher) and ICT use outside of the classroom, which includes ICT use at home and ICT use outside of class but not at home (whether in a school computer lab, a library, or at any other location except home). For the sake of simplicity, ICT use subsumes all of the above situations in the remainder of this text, unless otherwise noted.

[2] Although parents' role in facilitating and shaping students' access to and use of ICT resources is well documented, the potential absence of a parent questionnaire in PISA 2022 might restrict the ability to cover these aspects.

[3] Global competence encompasses multiple dimensions. A globally competent student can examine local, global and intercultural issues, understand and appreciate different perspectives and world views, interact successfully and respectfully with others, and take responsible action toward sustainability and collective well-being (OECD, 2018[10]).

[4] Advantaged/Disadvantaged students are students in the top/bottom quarter of the PISA index of economic, social and cultural status.

[5] Bundsgaard and Hansen (2011[26]) actually refer to functional, semantic and "didacticised" learning materials. In their terms, "Functional learning materials (tools) characterised by their *facilitation of learning and teaching*" include black and white boards, computer applications, projectors, and mobile phones. "Semantic learning materials (texts) characterised by their *meaning as constituted by signs and semantic references*" correspond to film, literature, etc. Finally, "Didacticised learning materials, characterised by *combining tools and text and facilitating learning and teaching*, include textbooks, online teaching materials and educational games".

[6] Note that the discussion leans towards the quality of ICT resources for learning, but similar dimensions can be used to uncover the quality of ICT resources for leisure. Moreover, aspects related to the intrinsic relevance and suitability of ICT resources when used for teaching are not covered here.

[7] In this case, the nature of instruction also shifts from teacher-supervised learning with ICT to unsupervised learning with ICT.

Annex A. PISA Reading Framework

The PISA reading framework received its most recent major updates when it was the major domain of assessment in PISA 2018. It retained aspects of the PISA 2009 and 2015 frameworks that were still relevant to PISA 2018 and 2022. However, for PISA 2018 and onwards the framework was enhanced and revised in the following ways:

- The framework fully integrated reading in a traditional sense together with the new forms of reading that have emerged over the past decades and that continue to emerge due to the spread of digital devices and digital texts.
- The framework incorporated constructs involved in basic reading processes. These constructs, such as fluent reading, literal interpretation, inter-sentence integration, extraction of the central themes and drawing inferences, are critical skills for processing complex or multiple texts for specific purposes. If students fail at performing higher-level text processing functions, it is critical to know whether the failure was due to difficulties in these basic skills in order to provide appropriate support to these students.
- The framework revisited the way in which the domain is organised to incorporate reading processes such as evaluating the veracity of texts, seeking information, reading from multiple sources and integrating/synthesising information across sources. The revision rebalances the prominence of different reading processes to reflect the global importance of the different constructs, while ensuring there is a link to the prior frameworks in order to be able to measure trends in achievement.
- The revision considered how new technology options and the use of scenarios involving print and digital text can be harnessed to achieve a more authentic assessment of reading, consistent with the current use of texts around the world.

Please see the full version of the reading framework in the following link: PISA 2018 Assessment and Analytical Framework | en | OECD

Annex B. PISA Science Framework

The PISA science framework received its most recent major updates when it was the major domain of assessment in PISA 2015. This framework for PISA 2015 was used also in PISA 2018 and 2022. It refined and extended the previous construct, which had been developed in the PISA 2006 framework that was also the basis for assessment in 2009 and 2012.

Scientific literacy is developed through science education that is both broad and applied. Thus, within this framework, the concept of scientific literacy refers both to a knowledge of science and of science-based technology. However, science and technology differ in their purposes, processes and products. Technology seeks the optimal solution to a human problem and there may be more than one optimal solution. In contrast, science seeks the answer to a specific question about the natural material world.

Scientific literacy also requires not just knowledge of the concepts and theories of science but also a knowledge of the common procedures and practices associated with scientific enquiry and how these enable science to advance. Therefore, individuals who are scientifically literate understand the major conceptions and ideas that form the foundation of scientific and technological thought; how such knowledge has been derived; and the degree to which such knowledge is justified by evidence or theoretical explanations.

Please see the full version of the science framework in the following link: PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving | en | OECD

Annex C. PISA 2022 Expert Groups

Mathematics Expert Group (MEG)

- Joan Ferrini-Mundy (University of Maine, United States)
- Zbigniew Marciniak (University of Warsaw, Poland)
- William Schmidt (Michigan State University, United States)
- Shuchi Grover (Stanford University, United States)
- Takuya Baba (Hiroshima University, Japan)
- Jenni Ingram (University of Oxford, United Kingdom)
- Julián Mariño (University of the Andes, Colombia)
- Stefania Bocconi (National Research Council of Italy (CNR) Institute for Educational Technology, Italy)

Extended Mathematics Expert Groups (eMEG)

- Michael Besser (Leuphana University of Lüneburg, Germany)
- Jean-Luc Dorier (University of Geneva, Switzerland)
- Iddo Gal (University of Haifa, Israel)
- Markku Hannula (University of Helsinki, Finland)
- Hannes Jukk (University of Tartu, Estonia)
- Christine Stephenson (University of Tennessee, United States)
- Tin Lam Toh (Nanyang Technological University, Singapore)
- Ödön Vancsó (Eötvös Loránd University, Hungary)
- David Weintrop (College of Information Studies, University of Maryland, United States)
- Richard Wolfe (Ontario Institute for Studies in Education, University of Toronto, Canada)

Financial Literacy Expert Group (FLEG)

- Carmela Aprea (University of Mannheim, Germany)
- José Alexandre Cavalcanti Vasco (Securities and Exchange Commission, Brazil)
- Paul Gerrans (University of Western Australia, Australia)
- David Kneebone (Investor Education Centre, Hong Kong (China))
- Sue Lewis (Financial Services Consumer Panel, United Kingdom)

- Annamaria Lusardi (George Washington University School of Business and Global Financial Literacy Excellence Center, United States)
- Olaf Simonse (Ministry of Finance, Netherlands)
- Anna Zelentsova (Ministry of Finance of the Russian Federation, Russia)

Creative Thinking Expert Group (CTEG)

- The CTEG included Ido Roll (Technion - Israel Institute of Technology, Israel)
- Baptiste Barbot (Université Catholique de Louvain, Belgium)
- Lene Tanggaard (Aalborg University, Denmark)
- Nathan Zoanetti (Australian Council for Educational Research, Australia)
- James Kaufman (University of Connecticut, United States)
- Marlene Scardamalia (University of Toronto, Canada)
- Valerie Shute (Florida State University, United States)

Questionnaire Expert Group (QEG)

- Nina Jude (Leibniz Institute for Research and Information in Education until 2020, then Heidelberg University, Germany)
- Hunter Gehlbach (University of California, Santa Barbara until 2019, then Johns Hopkins University, United States)
- Kit-Tai Hau (The Chinese University of Hong Kong, Hong Kong (China))
- Therese Hopfenbeck (University of Oxford, United Kingdom until 2022, then University of Melbourne, Australia)
- David Kaplan (University of Wisconsin-Madison, United States)
- Jihyun Lee (University of New South Wales, Australia)
- Richard Primi (Universidade São Francisco, Brazil)
- Wilima Wadhwa (ASER Centre, India)

ICT expert group

- Michael Trucano (World Bank, United States)
- Jepe Bundsgaard (University of Aarhus, Denmark)
- Cindy Ong (Ministry of Education, Singapore)
- Patricia Wastiau (European Schoolnet, Belgium)
- Pat Yongpradit (Code.org, United States)

PISA

PISA 2022 Assessment and Analytical Framework

This report presents the conceptual foundations of the OECD Programme for International Student Assessment (PISA), now in its eighth cycle of comprehensive and rigorous international surveys of student knowledge and skills that are essential for full participation in modern societies. As in previous cycles, the 2022 PISA assessment covered reading, mathematics and science, with a major focus on mathematics, plus an evaluation of students' creative thinking and financial literacy skills. This publication includes the frameworks for assessing mathematics, financial literacy and creative thinking. These chapters outline the content knowledge and skills that students need to acquire in each domain, how each domain is assessed, and the contexts in which this knowledge and these skills are applied. The publication also presents the frameworks for the various questionnaires distributed to students, school principals, parents and teachers, including a new Global Crisis Module (GCM) for students and school principals. It concludes with the framework for the Information and Communication Technologies (ICT) familiarity questionnaire distributed to students.

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